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PROMOTION OF THE MECHANIC ARTS.

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EDITORIAL.

ITEMS AND NOVELTIES.

Planing of Metals.—The distinguished French Physicist and Engineer, M. Tresca, gives at the end of a long and elaborate memoir upon the planing of metals, recently published in the *Bulletin de la Société d' Encouragement*, the following exceedingly valuable conclusions:—

1. The operation of planing produces, in the prism of matter cut by the tool, characteristic pressures and deformations, which vary according to the form of the tool and the thickness of the prism removed.

2. These circumstances are more easy to define where the case is that of planing done over the whole breadth of a solid by means of a tool with a straight edge, and a cutting surface, plane or cylindrical, in which the generating lines are perpendicular to the direction of the movement, and parallel to the surface of the solid planed. With these conditions the shaving detached is a transformation of the original prism, produced by diminution of its length, in consequence of a transverse flowing (*ecoulement*) of matter in the direction of the thickness of the shaving, under pressure of the tool.

3. The co-efficient of longitudinal contraction depends on the degree of sharpness of the tool, the facilities it offers for disengagement

of the shaving, but, above all, the thickness of the shaving removed. The co-efficient of reduction is smaller for thin shavings, because the flowing in the transverse direction is then rendered easier.

4. The co-efficient of dilatation, in the thickness, is inversely as the co-efficient of reduction in the length.

5. The co-efficient of reduction varied, in the whole series of experiments made, from 0·10 to 0·60, and we possess shavings of steel of more than a millimetre in thickness, for which it does not exceed 0·25.

6. The surface of separation between the shaving and the block is always smooth, and is modeled on the cutting face of the tool. The opposite face is always striated, and presents the appearance of a series of parallel waves, which are more salient, the thicker the shaving. These waves continue to the edge, where we find indications of a flow in width, limited to a very small extent, commencing at these edges. In fine cuttings the striæ, which are much finer, impart a velvety appearance to the whole surface.

7. A circumference traced on the exterior face before planing is transformed into an ellipse, in which the relation of the two axes affords the measure of the co-efficient of reduction; but it is best to obtain it by operating with great lengths.

8. When the deformations exceed certain limits, the shaving is split at intervals, and there is a disjunction in the directions in which lie the furrows of the waves.

9. When the tool is blunted, the co-efficient of reduction diminishes, and the planing becomes more difficult.

10. The cylindrical form of the tool is very favorable to the operation, and an examination of the deformations leads us to the conclusion that the hyperbolic form is the most recommendable.

11. In virtue of the pressure exerted by the cutting face of the tool on that of the shaving, the latter emerges perpendicularly to the surface of the solid, thereupon turning round. Thin shavings become rolled up in the form of a cylinder with spiral base, the windings exactly covering each other. The radius of rolling increases with the thickness.

12. When the generating lines of the cylinder which forms the side of the cutting-face of the tool are inclined relatively to the plane of motion, the shaving, instead of being rolled up cylindrically, takes the form of the exterior surface of a screw with square thread.

13. The lateral attachment of a conical shaving by one or other of its edges has no sensible influence on the result of the planing. The co-efficient of reduction remains the same, but the edges originally engaged are less round, and are even cut sharply in one part of the thickness of the shaving.

14. When the dimension in thickness becomes comparable to the dimension in width, there is a dilatation in both directions, and the shaving takes a quite particular form, of triangular section, which is readily deduced from certain geometrical considerations.

15. The employment of a tool with a curved edge gives rise to similar transformations, which are explained in the same way.

16. From the geometrical point of view the formation of shavings may be represented in all its phases by geometrical traces, according to perfectly sure rules. In a first phase, that of driving back (*refoulement*), the matter not yet detached from the block, acquires, in each of its longitudinal sections, its definitive dimensions in thickness and width. In a second phase, that of flowing, the shaving slides on the face of the tool, and acquires its definitive section. In a last phase the shaving escapes, turning round, according as the co-efficients of reduction imposed on its different longitudinal sections exert on them an influence more or less preponderant.

17. With the rectangular tool, having equal angles, a shaving of square section is liberated in the bisector plane of the dihedral figure formed by the two faces removed, giving rise to a deformation more complex, but quite as plausible as that of ordinary shavings.

18. With the tool having a curved edge the effects are of the same order, and bring to light the mode of driving back of a solid brought to the state of fluidity under the action of the exterior pressures to which it is subjected on one of its faces. The gorge-curve, which is produced at the limit of the two first phases of the formation, is quite characteristic, and leaves its impress on the originally free face of the shaving, under the form of curved furrows, which are reproduced identically the same throughout the whole length.

19. In the shavings, the breadth is approximately determined by the chord which joins the extremities of the crescent detached at each passage of the edge.

20. The convexity of the shaving appears generally at the thicker border, and there is no exception to this, save in cases where the relative sharpness of the tool exerts, on the thin parts, an influence strong

enough to compensate that of the more favorable co-efficient of reduction corresponding to the thicker border.

21. The more complex kinds of planing, such as work with the lathe, on circumference or extremity, do not introduce any notable change into these conclusions; which are thus quite general.

22. The work necessary to produce planing is composed of a work of cutting and a work of deformation, each represented by rational formulæ.

23. These formulæ show the advantage of the thick passages (*passes*) which mark the present tendency in the industry of machine tools.

24. The pressure exerted by the tool is transmitted from transverse section to transverse section up to the limit of the zone of activity, according to a logarithmic law deduced from these formulæ.

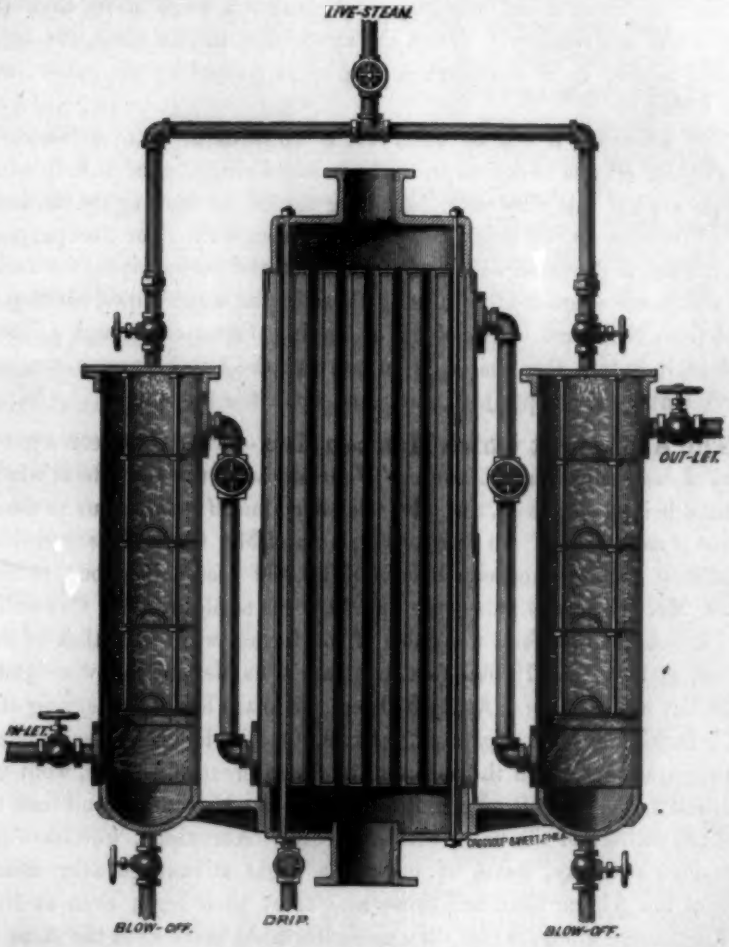
25. Lastly, and it is the ruling character of this work, the hardest as the softest, metals are subjected in all these deformations to common laws which establish, for all the matter experimented with, an identity hardly suspected, hitherto, in their mechanical properties, even beyond their limit of elasticity.

26. The preceding effects are perhaps not without interest for the theory of the plough, which one may consider as a planing tool acting under special conditions.

Combined Feed-Water Heater and Filter.—At the stated meeting of the Institute for November, there was exhibited and described, the apparatus herewith illustrated, the invention of Mr. William T. Bate, of Conshohocken, Pa. The device is a combined feed-water heater and filter, and its purpose, as designed by the inventor, is to remove scale-producing and other impurities from feed-water for steam boilers, by forcing the feed-water, in its course towards the boiler, through an apparatus in which are combined a heater and cold and hot water filters.

The apparatus consists of the heater, which is a cylindrical iron vessel of adequate strength, provided with a series of tubes or passages to conduct the exhaust steam of the engine, and openings above and below, as shown in engraving. To the right and left of this heater, and communicating with it by pipes, are stationed the cold and hot water filters. These are duplicates of each other, and are provided with a series of perforated platforms, sustained in place by uprights. The object of this arrangement is to prevent the matting

together of the filtering material, which would speedily take place were it left unsupported.



The operation of the device is about as follows: The feed-water is introduced into the lower portion of the cold water filter through the inlet, and is forced upwards through the successive sections of the filtering material (cotton-wool is usually employed), and is passed through the connecting pipe into the heater, having been deprived of the bulk of its mechanical impurities in its passage. In the heater, the feed-water has the heat of the exhaust steam imparted to it through the tubes, and is forced from the upper part of the vessel by

a communicating pipe into the bottom of the second filter, where any residue of mechanical impurity, and doubtless some of its chemical impurities are retained. From the upper part of this filter, the feed-water, heated to a considerable degree, is passed by the outlet into the boiler.

The filtration, it will be observed, is upwards in both instances—the object of this being to prevent the rapid clogging of the filtering material; but this may, after becoming fouled, be thoroughly cleansed in a few minutes, by forcing live steam through it. For this purpose each filter is provided with live steam inlet and outlet pipes, the cocks in which are opened after closing those in the water pipes leading to and from the filters. The object of leading the water through a filter, before it enters the heater, is to prevent the latter from becoming inefficient by the deposit of mud, etc., upon the tubes. W.

The Altitude at which Men can live.—There has been a great deal of discussion, says *Chambers' Journal*, as to the altitude at which human beings can exist, and Mr. Glaisher himself can tell us as much about it as anybody. In July, 1872, he and Mr. Coxwell ascended in a balloon to the enormous height of 38,000 feet. Previous to the start, Mr. Glaisher's pulse stood at 76 beats a minute, Mr. Coxwell's at 74. At 17,000 feet, the pulse of the former was at 84, that of the latter, at 100. At 19,000 feet, Glaisher's hands and lips were quite blue, but not his face. At 21,000 feet, he heard his heart beating and his breathing became oppressed. At 29,000 feet, he became senseless; notwithstanding which the aeronaut in the interest of science, went up another 8,000 feet till he could no longer use his hands, and had to pull the strings of the valve with his teeth. Aeronauts, who have no exertions to make, have, of course, a great advantage over members of the Alpine Club and those who trust their legs; even at 13,000 feet these climbers feel very uncomfortable, more so in the Alps it seems than elsewhere. At the monastery of St. Bernard, 8,117 feet high, the monks become asthmatic, and are compelled to descend frequently into the Valley of the Rhone for—anything but a breath of fresh air; and at the end of ten years' service, are obliged to give up their high living and come down to their usual level. At the same time in South America there are towns such as Potosi, placed as high as the top of Mont Blanc, the inhabitants of which feel no inconvenience. The highest inhabited spot in the world, however, is the Buddhist Cloister of Hanle in Thibet, where twenty-one priests live

at an altitude of 16,000 feet. The brothers Schlagintweit, when they explored the glaciers of the Ibi-Gamin in the same country, encamped at 21,000 feet, the highest altitude at which a European ever passed the night. Even at the top of Mt. Blanc, Professor Tyndall's guides found it very unpleasant to do this, although the Professor himself did not confess to feeling as bad as they. The highest mountain in the world is Mount Everest, in the Himalaya, 29,000 feet, and the condor has been seen "winging the blue air" 500 feet higher. The air, by the by, is not "blue," or else, as De Saussure pointed out, "the distant mountains which are covered with snow, would appear blue also;" its apparent color being due to the reflection of light.

Fatty Matter in Feed-Water of Boilers.—It is known that a quantity of fatty matter in the feed-water of a boiler causes a deposit which is not wet by water, and that this may lead to destruction of the boiler, inasmuch as the part of boiler side under the incrustation becomes more heated than other parts, and is apt to occasion rupture. A case of this kind, observed by M. Birnbaum, of Carlsruhe, has formed the subject of an investigation which he describes in a recent number of Dingler's *Polytechnisches Journal.*

The boiler in question had become leaky about two months after working had commenced, and most likely from a cause like that indicated, the incrusted boiler plates getting heated, and being bellied out by the steam pressure; when the boiler cooled, the metal sought to right itself, and thereby a force was developed, sufficient to tear the rivet holes

In the boiler there was found, besides a paper-thick coating of the usual deposit over the whole surface that was under water, a layer (from 2 to 3 mm. thick) of pulverulent matter, on the foremost half of the boiler bottom, which was a little inclined towards the fireplace. This powder was found very difficult to wet with water. Analysis showed that the incrustation contained a soap not soluble in water; there was at least 6 per cent. fatty acid present in the form of an insoluble soap. This fatty acid must have been neutralized by a certain quantity of lime or magnesia; and, to determine this, a quantitative analysis of the deposit was made. The result was:—Matter insoluble in muriatic acid (mud, sand), 16·83 per cent.; oxide of iron, 10·68; lime, 29·28; magnesia, 9·01; carbonic acid, 21·78; organic matter, 9·47; water, 2·77; total, 99·82 per cent. There was also present a small quantity of sulphuric acid, which could not be quantitatively de-

termined. If we suppose the whole of the carbonic acid combined with lime, this will take 27·72 per cent. of lime, so that 1·56 per cent. lime and 9·05 per cent. magnesia remain available for neutralization of the fatty acid (which is included in the organic matter in the above analysis). With the proviso that the fatty acid was mainly oleic acid the 1·56 per cent. lime would more than suffice to neutralize the acid; a portion of the alkaline earths must thus have been free, perhaps in the form of a basic carbonate, in the deposit. It appeared, at all events, from this analysis that the powder contained at least 7 to 8 per cent. of an insoluble soap.

A further point to determine was whence the fat of this soap had come into the boiler. On examination it appeared that the spring water used for feeding the boiler was peculiarly adapted for this. The water, however, was previously heated in a heater, by waste steam entering it directly from the engine. Through the introduction of this steam the water was diluted, then distilled water was added, so that the water from the heater might give less deposit than the spring water. But in addition to the pure water condensed from the steam, other matters were introduced in the heater, which conduced to increase the precipitation of deposit. These were partly of an inorganic, partly of an organic nature. Among the inorganic matters must especially be mentioned hydrated oxide of iron. It could not but be that through action of air and carbonic acid of the spring water, the iron sides of the heater should have been covered with rust, which should afterwards be dissolved and transferred to the water. The iron rust was, however, only suspended in the water; filtered water of the heater contained no iron. The quantity of organic matters introduced into the water by the steam was not insignificant. These also are not soluble in water; filtered water of the heater contained a less quantity of organic matter than the spring water. The water out of the heater was directly examined for fat and soap, and out of 6 litres water 0.017 gram isolated fatty acid was obtained. With a still larger quantity the filtered water was quite free from soap, while the unfiltered showed a quantity of insoluble soap. Thus it appeared that the spring water, through contact with steam, took up fatty matter in the heater; this fat formed a soap insoluble in water, suspended in the water along with hydrated oxide of iron. Volatile fatty acids, *e. g.*, butyric acid, which, in similar cases, have sometimes been found in feed water, were not observed by M. Birnbaum.

It follows as a practical result of this investigation, that the water in the heater should not be brought into direct contact with the waste steam. It is more rational to send the steam through pipes, over which the feed-water is made to pass. If the steam be sent direct into the water, in the heater, the danger arising from presence of fatty matter may be so far diminished by filtration of the feed-water. —*Iron.*

Cutting Steel Rails Cold.—The cutting of a file in halves with soft iron was an old lecture experiment. The soft iron formed a disc about six inches in diameter, mounted on a lathe-spindle and run at about 2000 revolutions per minute. A file held to the edge of the disc was cut in two in about ten or fifteen seconds, the disc being unharmed. The shower of sparks rendered this a brilliant experiment very popular with a general audience. The principle involved, says the *Engineer*, is now being applied to a practical purpose. Mr. Charles White, Manager at Sir J. Brown & Co.'s Works, Sheffield, has found the cost of cutting off the ends of steel rails cold, in the ordinary way, so enormous, that he resolved to try another expedient. For experiment, he had an ordinary rail-saw put in the lathe and all the teeth cut off. The revolving disc was then mounted on a spindle and driven at nearly 3000 revolutions a minute. The disc was three feet in diameter, so that its circumferential velocity was about 27,000 feet, or over five miles a minute, or 300 miles an hour. Steel rails forced against the edge of this disc were easily cut through in three or four minutes each. The rails weighed 65 pounds to the yard. Sparks flew in abundance, and the disc appeared to melt the rail before it; but after cutting five rails the disc itself was not sensibly warm. The experiment was such a complete success that the firm intend putting up a very powerful saw for the purpose of cutting cold steel rails.

The Pyrophone.—A novel and very remarkable musical instrument has recently been invented by M. F. Kastner, of Paris, which, it is said, produces astonishing effects even in the midst of the largest orchestras. It is termed by its inventor the pyrophone. The origin of the device is due to a curious discovery made by M. Kastner in the properties of singing flames. Many scientific men have studied these interesting phenomena, but the peculiarities of two flames in conjunction seems to have escaped their notice. As a result of his investigation, M. Kastner finds that if, in a tube of glass or other suitable material, two or more isolated flames of proper size be intro-

duced and located at a point corresponding to one-third the length of the tube, reckoning from the base, such flames will vibrate in unison. The phenomenon continues as long as the flames remain separate, but the sound ceases the instant they are brought in contact.

The pyrophone, at first sight, resembles an organ; but instead of being operated by air blown in, it produces its notes by the singing of the flames within the tubes, the quality of the sound, its pitch and intensity, depending, of course, on the dimensions of the latter. The burners from which the flames emerge are so arranged that the flames run together, but may be separated instantly by pressing down a key on an ordinary key-board in front. The position of the key in relation to the sound is the same as upon the piano or organ. According to the law above cited, as soon as a key is pressed the separated flames in the corresponding tube give forth a note, continuing, as in the organ, as long as the key is held down. It is said that the music thus produced is extremely beautiful, and that the sound closely resembles, in delicacy and purity, that of the human voice. The invention was patented in England last year (No. 1091), and is thus described in the specification:

The construction of this new or improved musical instrument, named the pyrophone, is based upon the musical instrument known as the chemical harmonicon.

It is well known that when a pure hydrogen gas-jet burns in a glass or china tube, or other vibrating material, a pleasant soft tone or sound is produced. The characteristic novelty of this improved instrument consists in the construction of the burners, and in the combined apparatus employed to act on these burners by means of the touch on the keys, similar to an ordinary piano, in order to obtain the sound or note required, or to stop it as required.

The burners are constructed with double oscillating branches or arms, in such manner that the two jets are brought into one by the contact of the two branches, while at the moment the sound or note is produced the two branches are separated, and form two distinct jets, which produce the vibration in the glass, china, or other tube which surrounds the branches of each jet or burner.

The improvements in the construction of the pyrophone consist—1. In dispensing with the inlet cock for the gas. 2. In the means employed for dispensing with the two cocks heretofore employed for regulating the passage of the gas to the two branches of each tube. 3. In a more simple arrangement of mechanism for transmitting the

movement of each key to its two corresponding branches.—*London Journal of Gas-Lighting.*

New Light of Intense Photographic Power.—MM. Delachanal and Mermet have recently presented to the French Academy a description of a new light of very great photographic intensity. The dazzling combustion of nitric oxide gas, after agitation with a few drops of carbon disulphide, is well-known. The authors have sought to utilize this light photographically by making it continuous. The lamp which they employ for this purpose is very simple in its construction, consisting only of a pint bottle having two openings through the cork, and filled with fragments of some porous substance, such as sponge, coke, or better, pumice, for the purpose of imbibing the carbon disulphide. Through one opening in the cork passes a tube which reaches to within a quarter of an inch of the bottom; through the other passes a considerably larger tube, about eight inches long. This latter tube may be of glass or of metal, and is closely packed with iron-scale. This is intended to act like the gauze in the safety-lamp, and to prevent the return of the flame into the bottle and its consequent explosion. The nitric oxide gas is passed into the bottle through the former tube above mentioned, and the gaseous mixture is conducted by a rubber tube to a kind of Bunsen burner, the air-holes of which are closed, and which is furnished with a small conical valve to regulate the flow of gas. This burner is also filled with iron-scale.

The nitric oxide gas is produced in the cold by the large apparatus of Sainte-Claire Deville, by the action of a mixture, in certain proportions, of nitric and sulphuric acids upon metallic iron. In one gas bottle, upon a layer of fragments of porcelain, the iron, in small bars, is placed; the other gas bottle is filled with the mixture of acids. The two are connected by a large rubber tube attached to the two tubulures near the bottom. The cork of the gas bottle containing the iron has a cock passing through it, to regulate the delivery of the gas. With an apparatus of quite moderate dimensions, a dazzling flame, measuring not less than ten inches in height, can be obtained, abundantly sufficient for the purpose of photographic work.

Among the experiments made in the laboratory of M. Franck de Villecholle, the photographer, the authors give the following: The lamp above mentioned used to illuminate the dark room was placed about six feet distant from an engraving; in five seconds, without using any lens or mirror to condense the light, an excellent

negative was obtained. A portrait of the photographer himself, placed at the same distance and under the same conditions, was obtained in fourteen seconds. In these experiments the products of combustion, sulphurous and carbonic gases, were conducted into the chimney, because otherwise they would annoy the sitter.

M. Franck estimates that the photographic power of the lamp is superior to that of magnesium, is twice as great as that of the oxy-hydrogen light, and three times as great as that of the electric light. Moreover, the flame which it gives is absolutely steady, and there is no fear of its sudden extinction, as there is with magnesium. The extent of surface of the flame permits the illumination of large surfaces, and the eyes can support its brilliance without being in the least affected. Finally, its cost is much less than that of either of the other lights.

These advantages lead the inventors to expect the practical introduction of the nitro-sulphide lamp, especially for photographic enlargements and reproductions, as well as for the reproduction of microscopic objects.

On examining this light by means of a spectroscope consisting of four prisms, a banded spectrum was obtained consisting of a series of brilliant lines close together. The inventors are now occupied with experiments to test the question whether this light, like that of magnesium and that produced by electricity, has the power of developing the green coloring matter of leaves.

Restoring Old Files.—M. Werderman has patented the following process for re-sharpening old files which have become useless by long wear: After thorough washing with a strong and hot solution of caustic soda, the files are put in connection with the positive electrode of a battery and plunged into a bath composed of 40 parts of sulphuric acid and 1000 parts of water. The negative electrode consists of a copper wire spiral surrounding but not touching the files, the end of the wire coming to the surface to be connected with the battery. After ten minutes of immersion, the files are withdrawn, washed, dried, and examined; if the cut is not sufficiently deep, they are replaced in the bath. Sometimes two operations are required, but rarely more. Files thus treated have, it is said, the appearance of new ones, and may be used constantly for sixty hours without losing their cutting power. The battery employed by M. Werderman is twelve Bunsen cells.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 18th, 1874.

The meeting was called to order at the usual hour, with the Vice President, Dr. Robert E. Rogers, in the Chair.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at their stated meeting, held on the 11th instant, the following donations to the Library were reported, to wit:

Annales des Ponts et Chaussées, for June, 1874. Paris. From the Editor.

Report of a Tour of Inspection of European Light House Establishments, made in 1873, by Major George H. Elliott. Washington, 1874. From the Author.

Report of the Investigating Committee of the Pennsylvania Railroad Company. Philadelphia, 1874. From the Company.

Annual Report of the Board of Regents of the Smithsonian Institution, for the year 1871. From the Smithsonian Institution.

Same, for the year 1872. From the same.

Smithsonian Miscellaneous Collections. Vols. 10, 11, 12. From the same.

Smithsonian Contributions to Knowledge. Vol. 19. From the same.

Chief Engineer's Monthly Report of the Manchester Steam Users' Association. July, August, 1874. From the Association.

British Patent Reports; with Index of Patents and Patentees, for 1871; and Statistical Tablet relating to the Colony of Victoria. London. From the Hon. Commissioner of Patents, and William H. Archer, Registrar General of Victoria.

Abridgements of Specifications relating to Safes, Strong Rooms, Tills, and similar repositories. 1801–1866. London, 1874. From the Hon. Commissioner of Patents.

Agricultural Report for 1872. Washington, 1874. From the Hon. Commissioner of Agriculture.

Les Chemins de Fer Anglais, en 1873. Par E. Malezieux. Paris, 1874. From the Author.

Proceedings of the Academy of Natural Sciences of Philadelphia. April to September, 1874. From the Academy.

Logarithms of Sines and Cosines, etc. Washington, 1874. From the Bureau of Navigation.

Geological Survey of Canada. Report of Progress. 1872–73. From the Director.

Technical Training. By Thomas Twining. From the Author.

Bulletin de la Société d'Encouragement. Vol. I., No. 8, 1874. Paris. From the Society.

Annales de Chimie et de Physique. July—August, 1874. Paris. From the Editor.

Verhandlungen der K. K. Geologischen Reichsanstalt, No. 7, 1874. Vienna. From the Director.

Jahrbuch derselben. Vol. 14, April to June, 1874. From the same.

Uber die Triadischen Pelecypoden, Gattungen, Daonella und Halobia. By Dr. E. M. v. Mojsvar. From the same.

Uber die Palaeozoischen Gebilde Podoliens and deren Versteinerungen. By Dr. Alois v. Alth. From the same.

The presiding officer next called upon Mr. William P. Tatham, Chairman of the Committee on Exhibition, who responded by stating that thus far the time had been insufficient to permit of a written report upon the late Exhibition, and he would therefore content himself with a verbal account of its history and results. He thereupon proceeded to give a historical sketch of the event, from its first suggestion, by Mr. J. Morgan Eldridge, to its close, recounting the manner in which the Institute obtained the use of the Freight Depot from the Pennsylvania Railroad Company, the raising of the guarantee fund, the enlargement of the Standing Committee on Exhibition to 100, the formation of the several sub-committees on rules, buildings, and machinery, space, transportation, correspondence, etc., paying a high compliment to the chairmen and members of these sub-committees for their untiring devotion to the arduous labors that devolved upon them, and especially to the energy and tact of the Superintendent of the Exhibition, Mr. J. B. Knight. The exact financial results of the event, he furthermore stated, it was at this time impossible to know, but it would, without doubt, be quite favorable.

Mr. Hector Orr followed with some remarks, in which he congratulated the Committee and the Institute upon the success of the late Exhibition.

Mr. J. W. Nystrom then presented a paper entitled the "Progress and Future of the Franklin Institute," in which the author, after alluding to the very wide-spread public interest in the affairs of the Institute, which the late Exhibition had undoubtedly created, urged for the proper advancement of its objects, that measures be set on foot to obtain the ownership of the lot upon which the Exhibition was held, upon which suitable buildings could be erected in time, in which the business of the Institute and its future Exhibitions could be held. The speaker urged that the Institute should be developed into an organization analogous to the South Kensington Museum in London, *i. e.*, with a technical school for the thorough training of mechanics and others in various branches of the useful arts, and exhibitions of arts and manufactures at stated periods. To realize this scheme in practice, the author contended, the Institute could confidently rely upon the liberality of its members, and their public spirited fellow-citizens, and likewise upon the legislature of the State. He concluded by offering the following preamble and resolution:

"WHEREAS, The Franklin Institute desires to maintain the lead in the promotion of the Mechanic Arts in this country, and

"*Whereas*, The proper performance of this high function transcends its present resources and accommodations; be it therefore

"*Resolved*, That a committee be appointed to inquire into the feasibility of securing a spacious lot in the centre of Philadelphia, for the purpose of erecting thereon a large and commodious building for the Franklin Institute and its future Exhibitions."

The presiding officer explained that the discussion of the resolution would properly be in place under the head of new business, and declared the postponement of the subject until that order of business was reached.

The Secretary's Report was next offered, which, besides a number of items of Engineering progress, included a description, illustrated upon the screen, of Mr. Wm. T. Bate's (of Conshohocken, Pa.) Combined Feed-Water Heater and Filter, and an exhibition of some samples of asbestos board, made by Mr. Rosenthal, of Philadelphia.

The discussion of Mr. Nystrom's resolution came next in order. The mover made some remarks in behalf of his motion, and was followed by Mr. Orr, in the same strain, who urged that if the public

were made aware of the fact that the Institute was making an earnest effort of the character contemplated in the resolution, the necessary pecuniary aid would be forthcoming.

Mr. Lippman urged the erection of a large building upon an appropriate site, the cost to be defrayed by the issuance of interest bearing bonds.

Mr. Charles S. Close earnestly opposed the project at the present time as inexpedient, and reminded its advocates of a former unfortunate speculation of this description that had crippled the usefulness of the Institute for years. If the money could be obtained wherewith to realize the project, he would certainly favor it, but he was utterly opposed to running the Institute into debt.

Dr. Rogers resigned the Chair to Mr. Orr, and took the floor, making a strong address endorsing the remarks just made by Mr. Close. He added thereto, that he did not deem an annual exhibition desirable.

Mr. Alexander Barry remarked, that in a few years, there would be a vast building in Fairmount Park, which the Institute might, in all probability, make use of for exhibition purposes whenever it desired.

Mr. G. Morgan Eldridge favored the resolution.

The resolution was thereupon put to the meeting, and was carried.

It was further decided that the committee should be five in number, the names to be announced at the next meeting.

Dr. Rogers spoke in flattering terms of the liberal action of the Pennsylvania Railroad Company, and of the obligation under which the Institute rested.

Mr. Orr thereupon moved that a committee be appointed by the Chair, to draft a testimonial expressive of the sense entertained by the Institute of its obligations to the Pennsylvania Railroad Company, for its liberal action in granting the use of its Freight Depot for the late Exhibition.

The motion was carried; and the Chairman, at the suggestion of the meeting, appointed Messrs. Close, Knight, Orr, Rogers (Ch'n.), Sellers (Coleman), and Tatham as members of that committee.

The meeting then adjourned.

WILLIAM H. WAHL, *Secretary.*

Civil and Mechanical Engineering.

ON THE METHODS OF TESTING STEAM ENGINES;

With a Description of the Trials of the Circulating Pumps on the U. S. S. "Tennessee."

By Geo. P. Hunt, P. A. Eng. U. S. Navy,
and
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It has been generally customary, in making experiments on steam engines in order to determine their economy, to measure the amount of coal consumed in performing a certain amount of work. These measurements give the commercial economy of the machine.

So long as all the machines compared are of the same design and dimensions, and the coal used is of the same kind and quality, and the pressure of the steam, the degree of vacuum, the rate of expansion, the temperature of the atmosphere, and all other circumstances are the same, it may be inferred that any difference in the economy is the result of some imperfection in the machine itself.

Or if there is a variation in one particular only, as, for example, in the pressure of the steam, the difference may be fairly assumed to be due to that variation; but if there are several variations at the same time, as, for instance, different kinds of engines or boilers, and different steam pressures, when there is any gain or loss of economy it is impossible to decide to which of the variations the change is due.

It may be that if a poorer economy shows in the case where there is used the higher steam pressure and greater expansion, then the power which was gained by the high steam pressure and great expansion, was lost, together with something more, in the increased condensation and leakage; or that where in addition there are also used different kinds of boilers in the two cases, that the power which was gained in the engine was lost in the boiler, or the reverse, leaving the final result the same.

Any differences in the kinds of coal used, or in the skill of the firemen, blend themselves inseparably with the other variations, and are indistinguishable from them in the final result.

An exhaustive series of experiments on all of even the important points of variation in modern steam enginery, *separately*, there only

being one variation in each experiment, would, even if practicable, take too long time and cost too much money to be even considered by any but a national power. Such experiments must be conducted on nearly the same sized machinery as that to which the results deduced are to be applied.

In attempting to compare the results of such experiments as he may find recorded, to determine the most economical design, the engineer finds that the experiments made especially for the determination of one certain point are generally not complete enough to serve any other purpose, and, in addition, that the experiments have generally been made by different observers under widely different circumstances and in widely separated localities; and, further, that the observer is almost invariably warped by some force, not necessarily of interest, but of opinion, to deceive even himself as to the actual conditions.

This last applies particularly to the reports which may be obtained from any new machine in the commercial world. For example, a steamship company substitutes in the place of an old ship of poor model, with old and nearly worn out engines and boilers, a new ship of greater capacity, finer lines, with new and improved machinery and boilers. They find by comparison of their accounts at the end of the year that the profits of the new ship are largely in excess of the old.

The engineer cannot separate the gain due to the increased size and improved model from that due to the improved machinery, much less the portion due to any particular variation from that due to the whole combination. If he would proceed surely to accomplish the same result he can only blindly copy the whole, unable to distinguish the good from the bad.

According to the dynamic theory of heat a certain weight of coal contains within itself a certain amount of work stored up, and ready to rush out under the necessary surroundings, as in the case of a compressed spring set free. The supply of a given weight of coal to the furnace of a steam boiler represents the application of a definite amount of force at one end of a series of transformations, a part of which force at length appears as useful work at the other, the balance having been wasted in the various processes through which it has passed.

Take, for example, a modern marine engine of the best construction and design. The force supplied to the furnace in the combusti-

ble is first developed as heat by the burning of the coal; a portion of this heat is utilized in changing the water into steam, the balance being wasted either in radiation or by being carried off in the hot gases through the chimney. A part of the steam formed is applied to move the piston, the balance being wasted by condensation against the sides of the pipes and cylinders, and by leakage past the piston or valves into the condenser. Only a small portion of the total force contained in the steam that is applied to move the piston is utilized, the balance escaping with the exhaust steam into the condenser. Of the force that is utilized in the cylinder only a portion performs any external work, the balance being absorbed in overcoming the back pressure and by the friction of the machine itself. Of the remaining small portion that may be applied to the screw another part is wasted in overcoming its useless resistances, and only the balance used to propel the ship.

The following figures represent approximately the *supposed* distribution of the total force in the best examples. No account is taken in them of the coal that is consumed in the various ways on board ship other than those mentioned, as, for instance, in getting up steam, for steam used to work pumps, for steam lost through the safety valves, for heat lost in blowing off, or remaining in the furnaces after the vessel has arrived in port. These and other causes usually add at least ten per cent. to the consumption, leaving the force utilized about *six* per cent. of the total force expended in the coal. The cost of an indicated horse power by the figures would be $2\frac{1}{2}$ lbs. of coal per hour, nearly.

		PER CENT.
Total heat in one hundred lbs. of anthracite combustible, in units of heat, . . .	1,400,000	
Deduct heat equivalent to weight of ashes, .	200,000	
Total heat in one hundred lbs. of anthracite coal,	1,200,000	100
Carried off by hot gases in chimney, . .	200,000	$16\frac{2}{3}$
Available to produce steam, . . .	1,000,000	$83\frac{1}{3}$
Lost by leakage and condensation, . .	200,000	$16\frac{2}{3}$
Available to perform work in cylinder, .	800,000	$66\frac{1}{3}$
Escaped with steam into condenser, . .	660,000	55
Transformed into work, . . .	140,000	$11\frac{2}{3}$
Absorbed in overcoming resistance of engine and load, ...	40,000	$3\frac{1}{3}$

		PER CENT.
Available to turn the propeller, . .	100,000	8⅓
Absorbed in useless resistances of screw or other propeller, ...	20,000	1⅔
Usefully applied to propel the ship, . .	80,000	6⅔

The owner of the ship only notices the first and last of these quantities, that is the amount of coal he has to pay for and the speed of his ship. The engineer may notice the amount of coal consumed and the indicated horse-power. They must, however, both remain in ignorance, without further experiment, of all the intermediate steps; steps by which at least 93 per cent. in the best cases, and 97 per cent. in the worst cases of the power supplied disappears.

The total amount of coal furnished may represent the amount of produce handled by a merchant to yield him a profit of six per cent. Would any man in any other case be satisfied with a system of accounts in his business which would leave him in ignorance of every thing but the gross outlay and the profits? We think not.

The actual amount of heat lost in each of the foregoing steps may be, with proper although inexpensive apparatus, measured for any practical case. That is, one may measure separately:—

1. The heat wasted in the chimney.
2. The heat lost by leakage or condensation.
3. The heat rejected with the exhaust steam.
4. The heat absorbed by overcoming friction and back pressure.
5. The heat lost by the inefficient action of the screw.

The first loss may be and has been measured in cases where the boilers furnished dry steam, by measuring the weight of water evaporated by a known weight of combustible, the water being measured in tanks, and the coal and water weighed. Knowing from former experiments the weight of water which would have been evaporated, if all the heat in the coal had been utilized, the difference between this and the weight actually evaporated is the portion lost, including both that lost from incomplete combustion and carried away in the hot gas and radiation. The quantity measured by the tanks would be the heat in the water corresponding to the number 1,000,000; and the heat lost to the number 200,000 in the example.

The second loss may be measured by subtracting the sum of the weight of steam delivered into the condenser, computed from the indicator cards and that condensed for the work done from the weight

of feed water supplied. The difference corresponds to the number 200,000 in the sixth line of the example.

The second loss may also be actually measured where the engines are furnished with surface condensers, by measuring the amount of condensing water, and computing the weight of steam necessarily condensed in the condenser to raise its temperature from the temperature of the injection to that of the discharge.

This method has the advantage of being an independent measurement, and also that a comparison of the feed water computed in this way with that measured in the tanks will show a true result whether the boilers are priming or not.

Having been assured that the boilers will furnish dry steam, the tanks for the measurement of the feed water may be dispensed with, without causing serious error in the deductions; for as the same water is used for steam over and over again, and as the only water that can leave the boiler must be in the shape of steam, either that steam must be condensed *en route* from the boiler to the condenser or in the condenser.

When the tanks for measurement of the feed water are dispensed with it may be fed to the boilers direct from the hot well as when the engines are running at sea; thus not only feeding the boilers with hot water in place of cold, but dispensing also with all the extra pumps and pipes necessary when the tanks are used. It will, however, be always better to use also these tanks for measuring feed water in any case, as a comparison of the measurements will give more accurate results.

Taken in conjunction with the measurement of the feed-water, the measurement of the condensing water will show with tolerable accuracy the amount of steam used and the amount of leakage and condensation.

Taken separately the measurement of the condensing water is to be preferred to the measurement of the feed water, because while either gives an accurate measurement of the steam used if there is no priming or leakage; the measurement of the condensing water gives the more nearly accurate result if there is.

Suppose for example, a case in which the boiler primed 20 per cent. of the water used; then while the engine used 80 lbs. of steam it would be charged by the feed water measurement with 100 lbs.

Error, $\frac{100 - 80}{100} = 20$ per cent.

If the terminal pressure in the cylinder were 10 lbs. and the temperature of the hot well were 120° the total heat brought into the condenser would be:

Steam, ...	80 lbs.		
Pressure, ...	10 "		
Total heat, ...		1172°·8	
Less Temperature, Hot Well,		120°	
Heat, per lbs. . . .		1052.8	
Total, . 80×1052.8			84124.
Water, primed, . . .	20 lbs.		
Temperature, on entering, .	193·9		
Less Temperature, Hot Well,	120		
Heat extracted, per lbs. .	73·9		
Total heat extracted from water $= 73{\cdot}9 \times 20$			1478
Total heat extracted from water and steam, =			85602.

This is the heat which would appear in the condensing water, and if it were all charged to the steam condensed the computed weight would be:

$$\frac{85602}{1052{\cdot}8} = 81{\cdot}3 \text{ lbs.}$$

The actual amount of steam was 80 lbs. Therefore the error:

$$\frac{81{\cdot}3 - 80}{81{\cdot}3} = 1{\cdot}6 \text{ per cent.}$$

The same reasoning applies to the leakage and condensation.

Knowing from former experiments the available heat in the weight of coal consumed, there are only four channels through which this heat may disappear, viz.:

1. With the gases through the smoke-stack.
2. Radiation from surface of boilers, pipes, etc.
3. By change into work.
4. Overboard with the discharge water.

If the boilers, cylinders, pipes, etc., are well lagged with non-conducting material, the radiation may be neglected, and we have:

$$\text{Efficiency of boiler} = \frac{\text{heat rejected in water} + \text{work,}}{\text{total heat in coal.}}$$

$$\text{Efficiency of engine} = \frac{\text{Work.}}{\text{heat rejected in water} + \text{work.}}$$

The "Tennessee" is a ship recently fitted with new machinery by Messrs. John Roach & Son, of the Morgan Iron Works, New York.

HULL.

Length on load line,	335 ft.
Length over all,	353 ft.
Beam,	45 ft.
Load draft (mean),	20 ft.
Displacement, (tons of 2240 lbs.)	4240
Mid-ship section,	678 sq. ft.
Estimated horse-power for a speed of 14 knots,	2900

MACHINERY.

A set of compound horizontal back-acting engines, there being two cranks at right angles, each crank being connected with one high pressure and one low pressure piston upon the same rod.

Number of high pressure cylinders,	2
Diameter " " "	40″
Number of low pressure cylinders,	2
Diameter " " "	78″
Stroke of all pistons,	40″
Condensing surface, outside of tubes,	8000 sq. ft.

BOILERS.

10 horizontal tubular boilers, 2 furnaces each.

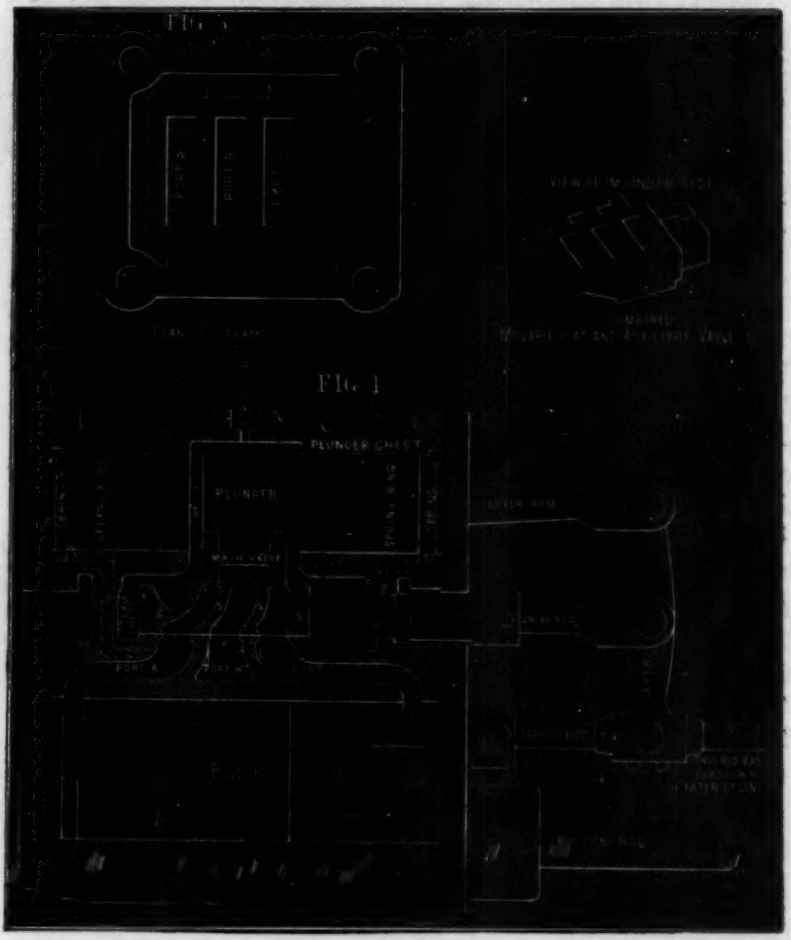
Total grate surface,	478 sq. ft.
Total heating surface,	12,835 "
Total super-heating surface,	1,000 "
Intended steam pressure, by gauge,	65 lbs.

It will appear from a comparison of the experiment with the following figures that the water necessary to condense the steam used by a set of engines sufficiently powerful to drive a ship of 4000 tons displacement through the water at a speed of 14 knots per hour could have been measured by a *single tank* similar to those used.

Indicated horse power,	2,900
Pounds of steam for each horse power, per hour,	20
Total weight of steam used,	58,000 lbs.
Temperature of hot well,	100°
Units of heat to be extracted from each lb. of steam reduced to temperature of hot well from temperature of terminal pressure in low pressure cylinder,	1,055

Total units of heat extracted,	61,190,000
Difference between injection and discharge,	50°
Pounds of injection-water necessary per hour,	1,223,800
Cubic feet of water necessary per hour,	18,958
Capacity of one tank at 72″ head with all holes open,	20,944
Excess of capacity,	9 per cent.

The independent circulating pumps were furnished by Messrs. Geo. F. Blake & Co., of Boston, Mass. They were selected for the "Tennessee" on account of occupying less space than any other pumps offered. The valve motion of the Blake pump has also an advantage over any other pump on the market. Fig. 4 shows a general sectional view of the steam cylinder, valve and valve chest, and Fig. 5 a plan of auxiliary valve seat.



The tappet rod passes through the heads of both steam and water cylinders, is moved in one direction on being struck by the steam piston just before reaching the end of the stroke, and the reverse when struck by the water piston. This arrangement allows the distance between the pump and the steam cylinder heads to be reduced to only that necessary to draw back the glands for packing. When the valve is moved by any tappet on the piston rod, the distance between the cylinder heads must be at least the length of the glands, plus the length of stroke.

The tappet rod is connected through a vibrating lever and stem to a casting which combines both the auxiliary valve and a movable seat for the main steam valve. The main valve is an ordinary "D" valve sliding upon the movable seat, and held between two shoulders of a supplementary piston or plunger.

The ends of the supplementary piston or plunger are fitted in their respective cylinders, which are cast in one piece with the main valve-chest, the outer ends of these cylinders being connected with openings under the auxiliary valve by little ports cast in the chest. These small ports lead from the auxiliary valve-seat towards each end of the supplementary cylinder, and are divided so as to enter at two different points, one through the head, and the other some distance from it, this last being covered by a piece of sheet brass acting as a valve which allows steam to enter the cylinder but opposes its exit.

In order to understand the action of the valve, consider the case when the piston is moving to the right. The movable seat or auxiliary valve having been previously moved to the left, the former partly closing the ports in the valve seat, the plunger and main valve will have been moved to the right, thus admitting steam to the left of the piston, and releasing it from the right. The piston moving steadily toward the right will, when near the end of its stroke, strike the tappet rod, moving it, and with it the auxiliary valve, first into position shown in Fig. 4. The ports to either end of the supplementary cylinders are closed, but the main steam port to the left and the exhaust port to the right end of the main cylinder are yet open, the main valve being still at the extreme right. The main piston being still exposed to the steam pressure continues on towards the right, and moves the auxiliary valve with it until the steam communication is opened by the small ports to the right end of the supplementary cylinder, and at the same time the steam in the other end is released.

The full pressure of steam then acts on the plunger or supplementary piston to move the main valve to the left and admits steam to the right hand end of the steam cylinder. At this instant the main piston is within a fraction of the end of its stroke, but may continue to move toward the end until the steam has had time to overcome the inertia of the plunger. When this has been overcome it moves rapidly to the left until the left end of the plunger has closed the branch port of the cylinder, and the other branch in the head being already closed by the brass valve the steam remaining in the cylinder cannot escape, and the supplementary piston is gradually brought to rest by the accumulating press between the piston and the head. During this interval the main piston commences its return stroke. So far the action is similar to the ordinary auxiliary valve motion.

In all steam pumps which have only this motion it will happen that when the pump is running very rapidly, as when it sucks air, that the piston will move past the point where the auxiliary valve admits steam to the plunger, and will strike the head before the steam has time to act upon the valve. But in this pump if the main piston continues towards the head it must draw with it the movable seat, until the right hand port passes the outer edge of the main valve, opening the port to steam, and the left hand port passes the inner edge opening the left end of the cylinder to exhaust. Under the above circumstances, the main piston will make a return stroke even though the supplementary piston and main valve should not have time to move at all.

(To be continued.)

Improved Chromolithographic Process.—Messrs. Johnson, of Hatton Garden, London, have invented a new and very economical process for producing chromolithographs. In place of using a special stone for each color, necessitating as many separate impressions as there are colors, the entire subject is drawn upon a single stone and a proof is taken on a thin sheet of copper. This sheet is then cut out carefully according to the desired contour of the colors, and upon each of the portions is fixed a solid block of color previously prepared. The whole is combined into one form, and is printed on an ordinary lithographic press, all the colors at once.

EFFICIENCY OF FURNACES BURNING WET FUEL.

AS DETERMINED BY EXPERIMENTS ON A LARGE SCALE.

By Professor R. H. Thurston, A. M., C. E.

A Paper read before the American Society of Civil Engineers, October 21st, 1874.

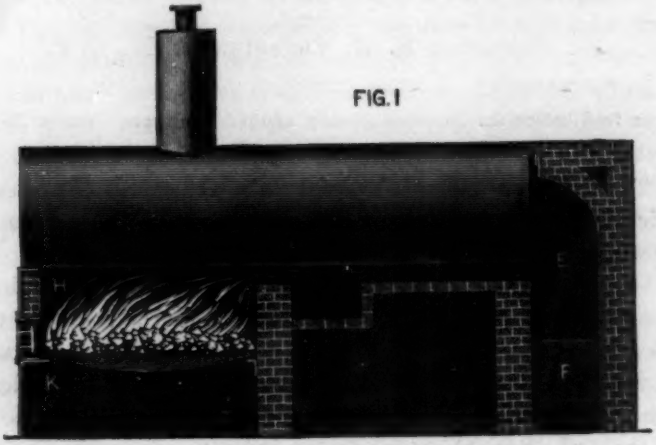
1. The writer was recently called upon in the course of professional practice, to determine the relative economical value of two forms of furnaces which were in use for burning wet fuel.

The use of fuel, like spent tan or sawdust, actually wet with water or sap, is so unusual, and is so seldom seen by the engineer, that a detailed account of an experimental investigation made upon two distinct varieties of furnace burning spent tan, wet from the leaches, will probably be considered as important and interesting, by the other members of the Society, as it was by the writer.

2. Formerly, it was thought impossible to burn this waste product of tanners, and it was either thrown away, at considerable expense for carting, or was mixed with dry wood or other good fuel at some cost, or it was dried in the open air by the sun, or by artificial heat in kilns. Within a few years, it has been found that with exceptional skill on the part of the fireman or "stoker," it could be burned with some success in furnaces only differing from those of ordinary construction by having a brick arch turned above the grates, in others having "cone" grates with special arrangement and proportions of air space, and with excellent results in a furnace having an overhead brick arch, with a grate so proportioned that a considerable amount of fuel could fall into the ash-pit and burn there, and with the separate "ovens," two or more in number, so arranged that the products of active combustion in one furnace should be mingled *en route* to the boilers, with the products of distillation and with moisture expelled from the fuel, in a similar adjacent "oven," or furnace, which fuel was, at the same time, drying under the heat radiated from the furnace walls and arch, and received from the fire in the ash-pit, thus desiccating preparatory to subsequent combustion. The latter requisite of preliminary desiccation, was secured also by a system of "alternate firing" of the separate feed-holes in the same oven.

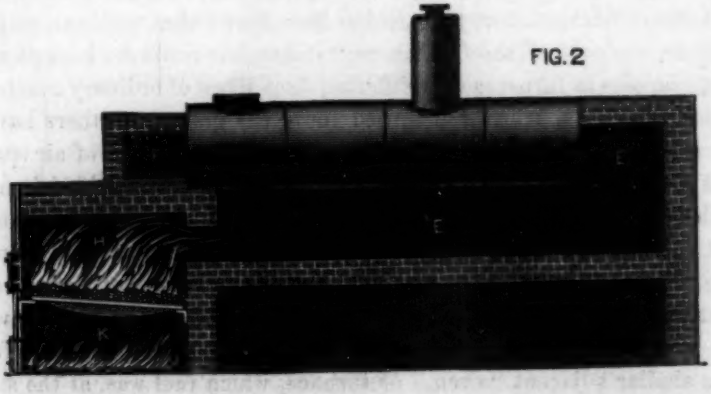
3. The secret of success would seem to be—as indicated by the examination of a large number and of a considerable variety of furnaces burning spent wet tan with more or less success—the surround-

FIG. 1



ing of the mass of wet fuel so completely with heated surfaces and burning fuel that it may be rapidly dried, and then so arranging the apparatus that thorough combustion shall be secured, and that the

FIG. 2



rapidity of combustion be very precisely equal to, and shall never exceed, the rapidity of desiccation. Where this rapidity of combustion is exceeded, the dry portion is consumed completely, leaving an uncovered mass of wet fuel which refuses to take fire, and then combustion ceased entirely.

In the ordinary steam-boiler furnace, Fig. 1, wet fuel has never, so far as the knowledge of the writer extends, been burned with even approximate success. Withdrawing the grates from under the boiler, and securing a reservoir and radiator of heat, by throwing over them a brick arch, as In Fig. 2, gives a form of furnace, known either as a Morrison or a Crocket furnace, in which wet fuel has been burned with partial success, and when the grates are so set that some fuel may fall into the ash-pit as it dries, and there burn, the conditions become those of the second case to be described. The use of the form of grate—shown in Fig. 3 (enlarged in Fig. 4)—giving ample space for fuel falling into the ash-pit, ensures still freer combustion. This peculiar form of section also secures freedom from warping when highly heated.

FIG. 3

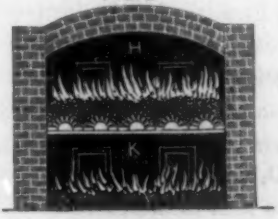
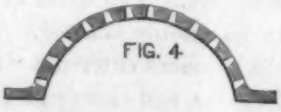
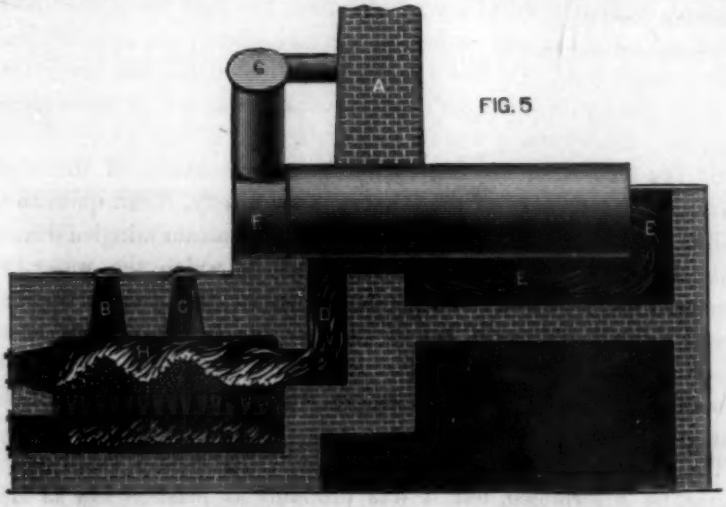


FIG. 4



4. The first example of a furnace burning wet tan, of which the efficiency was determined by the writer, was of the kind known as the "Thompson Furnace," which embodies all of the favorable conditions described in the preceding paragraph. This furnace is shown in section, Fig. 5.

FIG. 5



There were six "ovens" placed side by side, in two sets of three each, the chimney rising between them as shown at A. The grate

surface of each oven was 9 feet long, and 4 feet 4 inches wide, giving a total area of 234 square feet. Each furnace was charged through two holes, B and C, in the top of the furnace arch, the proper method being to fill these holes alternately. The grates were of fine brick, spaced about $\frac{3}{8}$ inch apart, and supported along the middle line of the ash-pit by a brick wall. The thickness of these grates was nearly 3 inches. They were in four pieces, breadthwise the furnace, a pair on each side the middle wall supported by abutting against each other in a manner somewhat resembling an arch of but two voussoirs. Two doors at the end of each ash-pit permitted cleaning to be readily effected. The gaseous products of combustion leaving the furnaces entered a "mixing chamber" D, common to each set of furnaces, and thence passed through the flues E E to the extreme end of the boilers, returning through the tubes to the smoke-boxes F, and through the iron flue G to the chimney.

5. The steam boilers were three in number, of the plain multitubular variety. Two were four feet in diameter, 14 feet in length, and contained 32 four-inch tubes each; the other was five feet in diameter, 12 feet long, and contained 78 three-inch tubes. The total heating surface, reckoning all of the tube surface, one-half the surface of the shell and all of exposed surface of the tube plates, was approximately 2000 square feet. Of this a portion was ineffective, the lower tubes being choked with ashes, and the remainder was partly covered with deposit. The chimney was 90 feet high.

6. The feed-water was heated by the exhaust steam of the engine driving the machinery of the tannery, very nearly, if not quite to the boiling point, in a closed heater. The exhaust steam mingled directly with the water. On reaching the tank in which the water was measured the feed water had cooled down to 205° Fahr.; thence it passed through the pump, and a considerable length of pipe across the street separating the engine from the boiler-house, and finally, around to the back end of the boilers, where branch pipes conducted it to each boiler.

The temperature of the feed when entering boilers could not, of course, be determined, but it was probably at least as low as 190° Fahr., which is the temperature assumed in the estimate of efficiency, and it may have been somewhat lower.

7. The measurement of the fuel was made as it lay on the leach, before it was disturbed for the purpose of being removed to the boiler-

house, this precaution being taken to avoid error arising from possible changes of volumes due to such disturbance. In one case this transportation to the furnace was performed by a screw, as grain is sometimes moved, and in the other case by cars, capable of carrying nearly a cord, into which the leach was thrown from the leach by hand, and then was dumped at the furnace doors. A careful measurement showed the full leach to contain 8·04 cords of tan. From this 0·34 cord was taken to be weighed after being compressed until it was, as nearly as could be judged, as compact as when in the leach.

8. Commencing at 9 o'clock A. M., the trial continued until the remaining 7·7 cords were burned, closing at 10 o'clock P. M.

9. The feed-water was measured by cutting the feed-pipe between the heater and the feed-pump, and conducting the water from the former into a wooden box 18 inches wide and four feet long. The pump drew the water from this box, which ordinarily stood full to the top. Occasionally, the water supply from the heater was shut off, and the time which was occupied by the pump in reducing the level of the water one foot was noted. This was invariably very precisely 4 minutes. The quantity of water pumped into the boiler from the beginning to the end of the trial was 5625 pounds, or 90 cubic feet per hour.

10. The capacity of the pump was originally barely equal to the requirements of the case, and, at this time, its valves leaked somewhat, making it necessary, not only to run the pump at its full speed throughout the trial, but to keep the fires considerably below their maximum intensity to avoid the necessity of putting on the steam auxiliary to prevent the water getting dangerously low. The maximum evaporation on the trial was thus determined by the capacity of the pump. The flue dampers were kept, as an average, something more than half open. The engineer estimated that he could have burned the fuel with nearly fifty per cent. greater speed, obtaining a proportionably increased evaporation, could the pump have supplied so much water.

11. The spent tan, coming directly from the leach, was so wet as to part with its water when squeezed, wetting the hand. It had been simply drained a few hours, and was as wet as it could be without dripping. The per centage of moisture is given below.

12. As the result of the trial was considered a matter of great importance, both directly and indirectly, it was essential, not only to

determine the amount of water entering the boilers, but to determine as accurately as possible the quality of the steam made, thus ascertaining how much water left the boilers as steam, and how much was "primed" over from them unevaporated. As, under the conditions of this trial, each pound of steam obtained from the fuel about eight times as much heat as was taken up by water "primed" out of the boiler, the serious error which might arise by crediting the fuel with the evaporation of all the water entering the boiler, in cases where even a moderate amount of priming occurred, is evident. Instances sometimes occur in which more water passes off unevaporated than is actually turned into steam. At least one instance has occurred in the experience of the writer in which the average amount of water primed exceeded by more than one hundred per cent. the weight of steam made, the percentage of priming as the expression is used in this paper, being over sixty per cent. The error arising from the neglect of this circumstance told nearly proportionally in favor of a really very poor boiler. A good boiler ought not to "prime," when working properly, over ten per cent. when unprovided with superheaters. Five per cent. priming would represent good work, and as low as three per cent. has been attained.

13. The first precise determination of the amount of priming in steam boilers was probably made by the writer in November, 1871, at a competitive trial of five steam boilers entered at the Exhibition of the American Institute, the trial being made at the request of a Committee of Judges of which he was then Chairman.*

In that instance, a large surface condenser of about 1100 square feet area of condensing surface was used, in which all of the steam made by the boiler on the trial was completely condensed. The water fed into the boiler was measured by a meter, and, on issuing from the condenser, was again caught in a tank. The condensing water, which amounted to some ten tons per hour, was measured by a meter.

The temperature of the injection and discharged water, of the feed, the steam, the water of condensation, and of the escaping products of combustion, were carefully ascertained by suitably arranged thermometers and pyrometers, and were recorded in a log kept by selected students of the Stevens Institute of Technology. The fuel and the ashes were weighed, and all data were obtained and recorded with the greatest possible care.

* Trans. American Institute 1871–2; Journal Franklin Institute 1872; Van Nostrand's Engineering Magazine, 1871.

RESULTS OF THE COMPETITIVE TRIAL OF STEAM BOILERS AT THE FAIR OF THE AMERICAN INSTITUTE, NOVEMBER, 1871.

NAME.	Square Feet. Grate surface.	Square Feet. Heating surface.	Ratio of Heating surface to Grate surface.	Total Weights. Coal.	Total Weights. Combustible.	Total Weights. Feed.	Total Weights. Steam.	Total Weights. Primed water	Ratio of water primed to water evaporated.	Mean Temperatures. Injection.	Mean Temperatures. Feed.	Mean Temperatures. Water of condensation.	Mean Temperatures. Discharge.	Mean Temperatures. Steam.	Mean Temperatures. Superheat.	Mean Temperatures. Flues.
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	O.	P.
Root	27	676½	32·5	3,800	3,165·5	27,896	27,896	0·	0·	45°·94	45°·94	56°·31	143°·1	334°·6	16°·08	416°·6
Allen	32¼	920	28·5	5,375	4,627	39,670	39,670	0·	0·	45°·6	45°·6	63°·48	154°·76	330°·63	13°·23	345°·87
Phleger	23	600	26·1	2,600	2,274	20,428	19,782·94	645·06	3·28	45°·65	45°·65	54°·38	120°·83	321°·06	0°·	503°·76
Lowe	37½	913	24·2	4,400	3,705	34,000	31,663·35	2,336·65	6·9	45°·0	45°·0	54°·8	131°·6	319°·48	0°·	389°·6
Blanchard	8½	440	51·8	1,232	1,047·5	10,132·5	9,855·6	280·9	3·	44°·4	44°·4	49°·49	106°·14	325°·75	0°·	221°·67

RESULTS, ETC.—(Continued.)

NAME.	Total British thermal units.	Total units per pound of combustible.	Apparent Evaporation. Per pound of combustible.	Apparent Evaporation. Per square foot of grate surface per hour.	Apparent Evaporation. Per square foot of heating surface per hour.	Actual Evaporation. Per pound of coal.	Actual Evaporation. Per pound of combustible.	Equivalent evaporation of water at 212° Fahr. and atmospheric pressure.	Square feet of heating surface required to evaporate one cubic foot of water per hour.	Coal, lbs. per square foot, Grate surface per hour.	Efficiency: actual evaporation of fuel divided by theoretical.
	Q.	R.	S.	T.	U.	W.	X.	Y.	Z.	Z 1.	Z 2.
Root	32,751,854·34	10,281·53	7·34	8·76	86·09	7·34	8·76	10·64	29·69	11·73	0·709
Allen	46,387,827·1	10,246·22	7·38	8·76	102·61	7·38	8·76	10·60	17·41	13·88	0·707
Phleger	23,068,686·39	10,143·66	7·26	8·95	73·70	7·07	8·70	10·49	22·74	10·13	0·690
Lowe	37,228,739·072	10,048·24	7·08	9·22	75·06	7·20	8·65	10·40	21·63	9·71	0·693
Blanchard	11,485,777·35	10,064·94	8·24	9·69	99·53	8·00	9·41	11·34	33·48	12·10	0·756

14. The tabular statement of the results, as given in the report of the Committee, is reproduced as they are not otherwise obtainable by engineers generally, and as they are interesting and valuable in themselves, and particularly, as affording a useful standard with which to compare the results obtained during this trial of tan-burning furnaces. The method of determining the percentage of priming will be given below. It should be stated that the Root and the Allen steam boilers were of the "safety" or "sectional" class; the Phleger boiler was also composed of small tubes, but was surmounted by a large drum which was intended to contain some water, thus differing essentially from the two preceding in construction, and in the fact that no portion of the heating surface was above the water-line. The Root and Allen boilers both had a considerable amount of superheating surface. The Lowe and the Blanchard were peculiar forms of multitubular boiler, the former being distinguished by having a peculiarly designed combustion chamber, and the latter by its unusually large proportion of heating surface, as compared with the area of grate, and by its dependence upon a forced draught. All of these boilers gave exceedingly creditable results at this test.

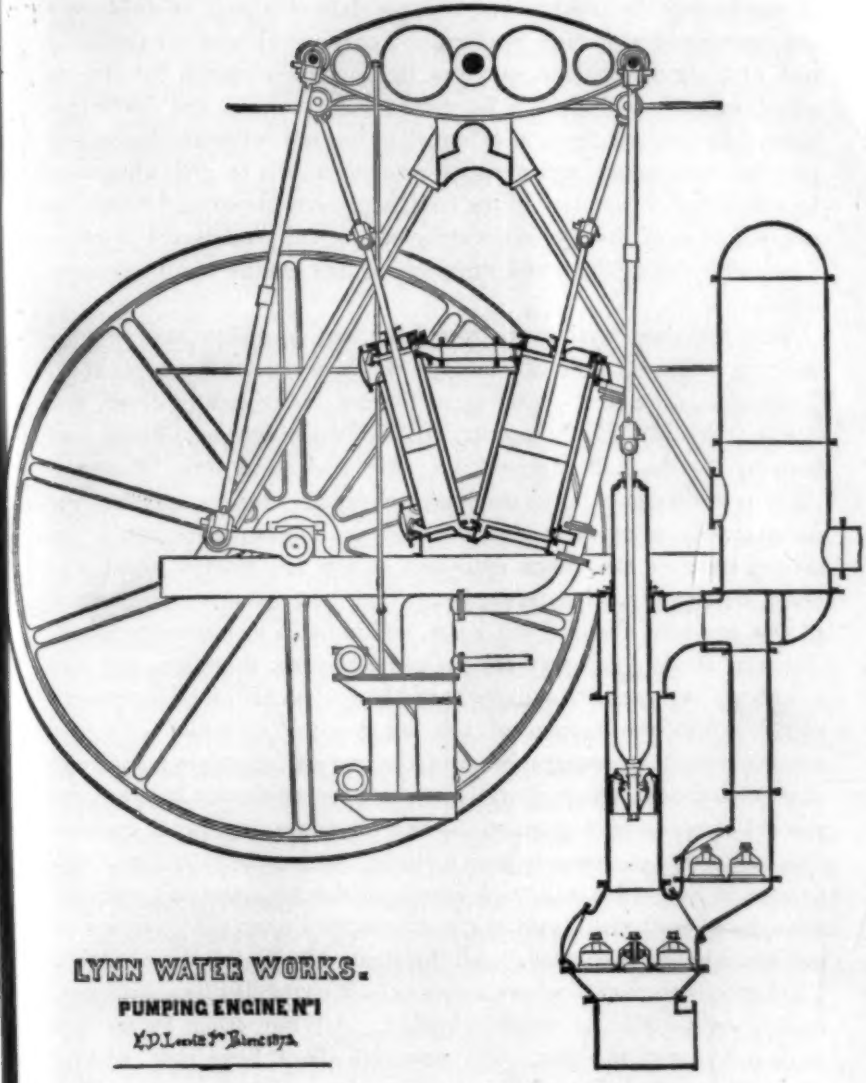
(To be continued.)

TEST TRIAL OF THE LYNN PUMPING ENGINE.

SECOND REPORT OF THE BOARD OF ENGINEERS, TO THE PUBLIC WATER BOARD OF LYNN, MASS.*

GENTLEMEN:—The object in presenting our First Report, of December 13, 1873, immediately after the conclusion of the test trial, was to enable your Board to make a settlement with the contractor for the engine. It was of primary importance, therefore, to give the results of the experiments, the capacity and duty of the pumping engine, requirements of the contract, rather than any description of the engine, or the manner of conducting the test; but it seemed that

*[A preliminary note upon the character and performance of this Lynn pumping engine appeared in this JOURNAL for January, 1874. The final report of the Board of Engineering Experts appointed to test this engine, appeared six months later. The novel construction of the engine and the exceptionally good performance of it at the time these tests were made, make it desirable in our opinion, to lay before our readers the essential portions of this Final Report, together with the First and partial Report as an appendix.—Ed.]


LYNN WATER WORKS.
PUMPING ENGINE N°1
L.D. Lewis Jr. Boston 1872.

something more than this brief report was due to ourselves and the engineering profession, and that a full record should be published, descriptive of the design and arrangement of the engine, the manner of conducting the experiments, and the data obtained, to enable any one conversant with such matters, not only to criticise our modes of test, and our conclusions, as given in the former report, but also to afford valuable information for future constructions and investigations. Subsequent revision of our data has not led us to change our previous conclusions, and what we propose now is to give what may be considered a narrative of the trial, a preservable copy, for our own use, and that of the profession especially, of our records and observations, with descriptions and drawings of the engine and its connections.

The pumping machinery, complete, was furnished and erected under a contract with Mr. George H. Norman, of Newport, R. I. The engine, compound cylinders, with beam, crank and fly-wheel, was designed by Mr. E. D. Leavitt, Jr., of Cambridgeport, Mass., and built by Messrs. I. P. Morris & Co., of Philadelphia, Pa. There are many novel features in the machine, which have been patented by the designer, the most noticeable of which, as shown in the cut, is the arrangement of the steam cylinders, which are located under the beam centre and incline outwardly, so that their pistons are connected to the opposite ends of the beam, and move in opposite directions. The top of the high-pressure cylinder exhausts, therefore, into the top of the low-pressure cylinder, and the bottom of the high-pressure cylinder into the bottom of the low-pressure cylinder. By this arrangement the passages between the two cylinders are made very short and direct. A single valve controls the connection between the two cylinders at the bottom, whilst two valves are used in the connection at the top, one close to each cylinder, so that the capacity of this passage is not added to the clearance of the high-pressure cylinder when being filled with steam, nor is it exhausted when the low-pressure cylinder is being exhausted. All the steam valves are gridiron slides. The high-pressure valves have a cam cut-off, controlled by a governor, readily adjustable to variable speeds. All the other valves are worked by positive cams. The cams are all of large radii, so that the opening and closing of the valves are almost instantaneous. Both cylinders are steam-jacketed at sides and ends, and, together with the steam connections, are clothed with asbestos covering and lagged with black walnut.

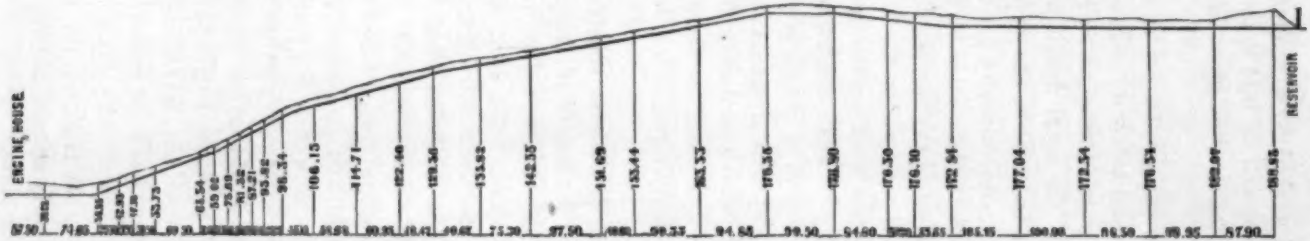
The air-pump is double-acting, and worked by a connection with the beam. The discharge from the hot-well is into the pump-well, and the boiler feed-water is drawn from the hot-well by an independent donkey steam-pump.

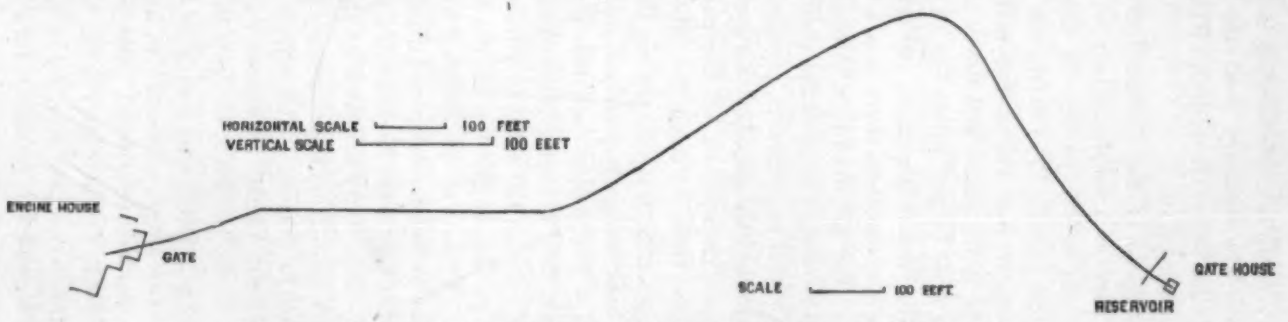
The pump is of the Thames-Ditton variety, bucket and plunger-pump. There is a supplementary pipe and valves to reduce the friction incident to the passage of the water through a single bucket valve in the piston. The valves are of the usual double beat form; the bottom, or foot valves, are seven in number, the upper valves three—one in the piston and two in the supplementary passage; each of the exterior bottom valves has an independent cover on the chamber, for the readier inspection and removal of the valves. To supply air to the air chamber, there is a small air-cock on the lower valve chamber. The air drawn in through this cock on the up-stroke of the pump somewhat reduces the quantity of water discharged by the pump. Careful experiments, previous to and in the early part of the test, established the effect of this cock, by measurements at the weir, and an uniform opening of this cock was kept during forty-eight hours of the trial. During the other four hours the average loss of action was a trifle less than during the forty-eight hours, during one hour the cock being completely closed.

Boilers.—The boilers are two plain horizontal tubulars, set in brick-work, fired beneath, flame passing the length of the boiler and returning through the tubes to a front connection, thence passing up into a single flue on the top of the boilers in brick-work, and to the chimney. There was no clothing at the front end of the boilers. There were automatic dampers attached to the boilers, but during the experiments they were disconnected and worked by hand.

Mains.—The water is drawn by the pump from a large well, supplied by a main from the collecting pond, and discharged through a twenty-inch force main. This main is of cast iron to the point marked gate in the cut, thence by cement-lined sheet-iron pipe of the same diameter, to the bottom of the gate-house in the service reservoir, and thence by a vertical cast iron pipe of sufficient height to discharge into a wooden trunk, connected with a weir box, where the capacity of the pump was determined. No record has been preserved of the exact position; the lines both in the horizontal and plans given in the cut, are from recent surveys, made since the trial, on the surface of the ground, and are probably very nearly approximative. On the main, there are two gates and one check valve.

PROFILE OF GROUND OVER FORCE MAIN FROM ENGINE HOUSE TO RESERVOIR.





PLAN OF LINE OF FORCE MAIN FROM ENGINE HOUSE TO RESERVOIR.

TABLE OF DIMENSIONS.

Diameter of high-pressure cylinder	17½	inches.
" low- " "	36	"
" high- " " piston rods	8	"
" low- " " piston rods	8¾	"
" air pump	11½	"
" pump-barrel	26 1-10	"
" plunger	18½	"
" bottom and supplementary valves outside lower seat	15⅞	"
" " " inside upper "	10	"
" piston valve, outside lower seat	22	"
" " " inside upper "	16½	"
" of fly-wheel	26½	feet.
Length of stroke of steam and water pistons	7	"
" " air-pump	49½	inches.
Distance between end centres of beam	14	feet.
Steam lead, high-pressure cylinder, top	0	
" " " " bottom	0	
" " low- " " top	0	
" " " " bottom	1-16	inch.
Exhaust lead, high-pressure " top	1-16	"
" " " bottom	1-16	"
" low- " " top	5 3-16	inches.
" " bottom	3	"

Closure before end of stroke:

High-pressure cylinder, top	9⅞	"
" " bottom	14 11-16	"
Low-pressure " top	6	"
" " bottom	5 5-16	"

Clearances:

High-pressure cylinder, top	.0231	of vol. of cylinder.
" " bottom	.0360	" "
Low- " " top	.0109	" "
" " bottom	.0104	" "
Top connection between cylinders	.0834	of high-press. "
Weight of fly-wheel	24,000	pounds.
" beams	9,500	"
" moving parts connected with beam	11,000	"

Boilers:

Diameter of shell	5	feet.
" drum	3	"
" tubes	3	inches.
Length of shell	16	feet.
Height of drum	6	"
Length of grate	5	"
Width of grate	5 feet 6	inches.

Force Main:

Length of force main from pump to top of vertical pipe at reservoir, 1,904 feet.
Height of top of vertical pipe above bottom of well 163·34 "

RECORDS OF THE TRIAL.

During the continuance of the test, one of the subscribing engineers was always on duty at the engine-house, often two, and sometimes four. The measures of the weir were taken by two members of the board, and the heights of the water over the weir were checked by them. Gauges and scale were carefully tested, and every provision was made to secure accuracy of observation and record. Mr. Hoadley, of our board, was, during the whole trial, on committee business at the State House, but had previously arranged with us the mode of conducting the experiment; had made a preliminary test with us, and was represented during this by his assistant, Mr. Huntoon.

Two watches of assistants were detailed, one for the engine-room, the other for the boiler-room, but were relieved in portion of their duties, from time to time, by the experts. Other assistants were employed in recording the heights of the water over the weir, and in dividing and measuring the indicator cards as taken from the steam cylinders and pump.

The duties of the assistants in the engine room, were to take indicator cards from each end of both cylinders hourly, to make observations, and records as follows:

RECORDS OF THE ENGINE ROOM.

Date.	Time.	Counter.	PRESSURES.				TEMPERATURES—DEG. FAHRENHEIT.					Depth of water in well.	FEED WATER.		
			Steam, lbs.	Vacuum, inches.	Water, lbs.	Barom., inches.	Steam.	Hot well.	Pump well.	Feed water.	Outside air.	ft. in	Cask No. 1. C'ks.	Cask No. 2. lbs.	Total lbs.
December 10...	11 a. m.	242,646	75½	27¾	63	30·14	325	98	40	91	37	8·1¼	3	850	200
December 12...	3 p. m.	300,003	75¾	28	63½	29·68	324	91½	41	96	38	8·1	373	310	130,240

The indicators were Richards' patent and Elliott & Co.'s make. They were carefully tested before the trial; and at about the middle of the trial the indicators on each cylinder were changed from one end to the other of the cylinder, so that half of the cards at the top and half at the bottom were taken by different indicators. The springs used in the high-pressure cylinder indicators were 32 lbs. to the inch; in the low, 16 lbs. to the inch. All the hourly cards taken from 9 A. M., December 10, to 3 P. M., December 12, have been divided,

measured, and re-measured, and will be found tabulated toward the end of this report.

It has not been considered necessary to publish the records of the engine room in full. The hourly readings of the counter, and the total quantity of water fed to the boiler will be thus given. Of the records of the other columns, the extreme readings and averages have been deemed sufficient.

The steam, vacuum and water gauges were attached to the engine frame, and connected as directly as possible with the steam-pipe, condenser and air chamber. At the conclusion of the trial, the steam gauge was tested and its reading was found to be 5 lbs. in excess, at the average of 75½ lbs., and should, therefore, be 70½ lbs. The vacuum gauge was not tested. As the estimate of duty was dependent on the reading of the water gauge this was carefully tested before and after the trial. Its reading at the average of 63·60 lbs. was found to be too small by 0·6 lbs., and should be therefore 64·20 lbs.

The barometer was an Aneroid, placed in the engine room. The records during the trial compare very nearly with the observations of the Signal Service Station at Boston. From the readings of the barometer, the zero on the indicator cards has been established, to which all pressures are referred instead of to the atmospheric line.

The temperature of the steam was taken by a Siefert thermometer, inserted into the main steam-pipe just outside the engine stop-valve.

The temperatures of the hot well were taken at its overflow into the pump-well after a passage of say 25 feet; the temperatures of the pump-well from a thermometer suspended therein; of the feed-water from the lower measuring cask; of the outside air from the front of the engine-house. The thermometers used for all the above observations were of Huddleston's make.

The depth of water in pump-well was taken from a scale in the engine-room, connected with a float in the well. The average reading was compared by ourselves with a bench mark on the wall, which had been referred to the top of the vertical pipe in the reservoir by one of Mr. Davis' assistants.

Feed-Water.—The quantity of water fed into the boilers was determined by an arrangement of casks of measured capacity. An upper cask (No. 1), which could be filled directly from the hot well and discharged into the lower cask (No. 2), which last was connected with a Blake donkey-pump, and was discharged into the boilers. Into cask No. 1, 350 lbs. of water, at 100° Fahrenheit, was weighed and dis-

charged, and at the level of the surface of the water an overflow was cut, so that the capacity of this cask was established at 350 lbs. of water. Outside of cask No. 2, a glass boiler-gauge was placed, connected with the bottom and top of the cask; and beside this gauge was a scale marked accurately to every 100 lbs. of water at 100° Fahrenheit, as it was weighed consecutively and poured into the cask. The working of this arrangement of casks is as follows: An assistant, exclusively in charge, closes the connection between the casks; fills No. 1 from the hot well, closes the connection between the hot well and opens that between the casks, and so continues filling into No. 1 and emptying into No. 2 as fast as drawn out by the feed pump, holding always some balance in the lower cask, and keeping tally of the total number of upper casks filled and emptied. At each hour the engine-room assistant receives the tally of cask No. 1, and notes by the scale on the glass gauge the quantity remaining in cask No 2. From the tally he knows how much water has been drawn from the hot well, and from his observation how much of this water still remains to be fed into the boilers.

Thus, at 11 A. M., December 10, three casks No. 1 had been filled and discharged into cask No. 2, and 850 lbs. still remained in the latter.

$$3\times350-850=200 \text{ lbs. fed into the boilers.}$$

At 3 P. M., December 12, 373 casks No. 1 had been filled and discharged into No. 2, and 310 lbs. remained in the latter.

$$373\times350-310=130{,}240 \text{ lbs. fed into the boiler.}$$

$130{,}240-200=130{,}040$ lbs. fed into the boilers between the hours of 11 A. M., December 10, and 3 P. M., December 12.

RECORDS OF THE BOILER-ROOM.

The coal used was egg and broken Lackawanna, of good average quality, as found in one of the Lynn coal yards. As no allowance was to be made for cinder or unconsumed coal, and as it was consistent with the method at the late trial of the pumping engine at Lowell, the contractor was permitted to cull or pick the coal, that as little incombustible material as possible might be charged to the boilers. Between the hours of 9.20 A. M. and 11.40 A. M., December 12, 149 lbs. were selected by the contractor from the screenings and fed into the grates. At the close of the trial there were 474 lbs. of cinders, 336 lbs. screened coal, and 355 lbs. of very fine coal from the grates. No account of any of the above quantities have been

taken in our estimates of duty or evaporation. The facts are only noted for comparison with other experiments in which evaporation has been predicated on combustible material.

The engine had been started on the afternoon of December 9 and run till 1.30 A. M., December 10. It was started again at 8.50 A. M., and some observations were taken at 9 and 10 A. M., but it was not till 11 A. M. that the trial commenced. At that time the fires beneath the boilers were in good working condition. The water in the boilers was at an established height, and the engine was making the number of revolutions which were found by the weir to give a discharge a little in excess of the capacity contracted for. These conditions were kept as nearly uniform as possible during the whole time of the trial, and when at 3 P. M., December 12, the test trial closed, the engine was still running at the same speed, and the fires continued to be kept in the same working conditions, whilst we made experiments on the quantity of water condensed in the steam jackets.

Two assistants, on alternate watches of about twelve hours each, had charge of the boiler-room observations, and had constant supervision, except when relieved by ourselves or other assistants at meals.

The coal was weighed in lots of 500 lbs. each in a permanent box on the scales, and left there to be drawn from according to the necessities of the fires. As each 500 lbs. was weighed it was set down in the column of gross weights.

In a column marked Separate Weights, was set down the balance left in the box after each firing, and the quantity taken from the box was set down under Grate Charges to boiler No. 1 or No. 2 where it was fired; but under the column Total Coal, was set down the amount of coal used in both boilers; thus, at 9.20 A. M., December 11, 500 lbs. were weighed and 10,500 had been previously weighed and fired. At 9.35 A. M., coal was fired on No. 2 grate, and 460 lbs. were left in the box. 500—460=40 lbs. was charged to No. 2, and the total was increased to 10,540. At 9.45 A. M., coal was fired on No. 1 grate, leaving 310 lbs. in the box. 460—310=150 lbs. was charged to No. 1, and the total was increased to 10,690 lbs. These quantities of coal and times of firing have been plotted on cross section papers, the ordinate divisions representing a scale of lbs. and the abscissa divisions one of hours. From an inspection of the profile thus constructed, the character of the firing may be readily understood. The absolute total fired at each hour may be interpolated, or the relative total properly chargeable at the time, reference being had to the character of firing

as shown previous to and after; whether it was light or heavy beyond an average grade line, that is, whether the fireman had been depreciating the character of the fire or improving it. The firing record was commenced before 11 A. M., December 10, and there was no coal fired between 2.45 and 3 P. M., December 12; and the quantities fired at 11 A. M. and 3 P. M. have been established from the grade line on the profile. With these exceptions, the total coal fired at each hour and hereafter given are the quantities interpolated by proportion between the two firings nearest the hour.

The pressures on the gauges of each boiler were observed and noted hourly. On comparison of these gauges with the standard, the reading of gauge, boiler No. 1, was found to be, excess, 2·5 lbs., and of boiler No. 2, 3 lbs. At the average reading, thus, No. 1 reading 76 lbs., should be 73·5 lbs., and No. 2, reading 77 lbs., should be 74 lbs.

Scales graduated to inches were placed against the glass water-gauges of each boiler, the zero being assumed at the height of one foot above the centres of the boilers, and the levels of the water in each boiler above or below the zero were noticed hourly.

The temperature of the feed water was taken from a Siefert thermometer inserted into the feed connection between the donkey-pump and the boiler.

A plugged pipe, filled with oil, was suspended in the main flue, at the top of the boilers, and the temperature of the flue was taken by inserting a Siefert thermometer into the oil.

It will be observed under column Remarks, "9:20 to 10:30, used steam from main boiler for feed." The engine has no pump connected directly with it, as at Lowell, and it has been usual to drive the donkey-pump directly from the boilers, but for the purposes of this trial it was thought best to drive the donkey by an independent boiler. Unfortunately, at times during the trial, the steam got too low in this boiler, and steam had to be drawn from the main boilers. Each time this occurred was noted, and the aggregate was found to be 8 hours out of the 52 of the trial. By experiments of Messrs. Copeland & Worthen, on the trial of Ridgewood Engine No. 3, December, 1869, it was found that one per cent. of the steam raised for the driving of the engine was used by the donkey. Adopting this basis for the 8 hours, it will be found that during this time as much steam would have been used by the donkey as would have been for the driving of a pump 52 hours, connected as at Lowell with the engine.

(To be continued.)

[Entered according to act of Congress, in the year 1873, by John Richards, in the office of the Librarian of Congress at Washington.]

THE PRINCIPLES OF SHOP MANIPULATON FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Continued from Vol. lxviii, page 339.]

Slotting Machines.

Slotting machines with a vertical cutting movement differ from planing machines in several principles to which the attention of the apprentice is directed.

First,—The tools are in most work held rigidly, in every direction, and not swerving from a pivot as in planing. This is necessary for two reasons; because the force of gravity can not be used to keep the tools in position and because the thrust or strain of the cutting falls parallel to the shank of the tools, and not transversely as in planing machines.

Second,—The cutting movement is performed by the tools and not by the material as in planing.

Third,—The cutting strain is at right angles to the face of the table, acting in the same direction as the force of gravity, and not parallel to the face of the table and the force of gravity as in planing.

The nature of the operation in slotting, and because of the rigid tools, the feed motion has to operate differently from that of a planing machine. The cross-feed of a planing machine may act during the return stroke but not so in slotting machines, the feed movement must take place at the end of the up-stroke after the tool is clearof the material, and as so much of the stroke as is made during the feeding action is lost it leads to the use of mechanism to operate the feed that has a quick abrupt action so as to save extra movement in the cutter bar.

This very interesting principle is overlooked and still oftener not understood among machinists, and will not fail to furnish an interesting example to be investigated, especially the action of the mechanism that operates the feed and the relations this movement bears to the cutter bar motion.

SHAPING MACHINES.

Shaping machines occupy a half-way place between planing and slotting machines, the movements corresponding more to that of slotting machines and the operations of the tools corresponding more to planing machines.

The advantage of shaping machines over planing machines for certain kinds of work is owing to the greater facilities afforded for presenting and holding small pieces or pieces of irregular shape, the supports or tables usually having both vertical and horizontal faces to which the work can be bolted; also in the accessibility and greater convenience of the mechanism for adjusting and feeding the tools.

Shaping machines are provided with adjustable vices, devices for planing circular forms, and other details that cannot be so conveniently used on planing machines. Another advantage of great importance in shaping machines is the positive range of the cutting stroke produced by crank motion, which stops the tool accurately at any point and permits planing of slots and key ways that can hardly be performed upon the common planing machine.

Shaping machines in common use are divided into two classes, one modification that has the lateral feed given to the tools, technically called traveling head machines, and the other with a feed motion of the table carrying the work, called table-feeding machines.

The first modification is better adapted to long pieces that are planed transversely such as cutting toothed racks, and the second to a shorter class of work where the hand adjustments are more frequent.

The most interesting study in connection with modern shaping machines are the principles of the cutting movements produced by the various devices, generally called quick return movements. These devices consist generally of modifications of the slotted lever or variable fulcrum principle, and what is known as 'Whitworth's' quick return motion.

As the intricacy of the subject renders it a difficult one to deal with except by the aid of diagrams, and as the mechanism can be seen in almost any machine fitting shop, I will merely call the attention of the learner to the movements and recommend them as one of the best subjects that can be chosen for diagram demonstration.

These quick return motions are a subject that will not wear out too soon, neither in interest nor in the amount of research that it admits of, and certainly is more useful than many of the nonsensical problems

that often take up time uselessly and have no application in practical mechanics.

The remarks relating to turning tools given in a former place apply to tools for planing as well, except that greater stiffness is required in planing tools, both of the edges and the shanks.

BORING AND DRILLING.

Boring, as distinguished from drilling, consists in turning out annular holes to true dimensions, while the term drilling is applied to perforating or sinking holes in the solid metal.

There is also a wide difference in the nature of the two operations that makes a greater distinction still. In boring, the action of the tool is guided by axial supports independent of the hole, while in drilling, the cutting edges are guided and supported mainly from their contact with, and bearing in, the material that is being drilled.

Owing to this difference in the manner of guiding and supporting the cutting edges, and the advantages of axial support for the cutting tools in boring, this operation is one of truth, by which the most accurate dimensions are attainable, while drilling is a comparatively imperfect operation, yet the ordinary conditions of machine fitting are such that nearly all small holes can be drilled with sufficient accuracy and at a much less cost than they could be bored.

Boring may be called internal turning, differing from turning in the cutting movement of the tool and in the cut being made on concave instead of convex surfaces; otherwise there is a close analogy to turning. Boring operations are to a large extent performed on lathes, either with boring bars or by what is termed chuck boring when the material is revolved and the tools are stationary.

Boring operations in the shop may be divided into three kinds: Chuck boring on lathes; Bar boring, when a boring bar runs on points or centres and is supported at the ends only; and Bar boring when the boring bar is supported in and fed through annular bearings.

The principles are different in each of these three plans of boring, and each are applicable to certain classes of work, and in certain cases one plan is right and another wrong.

A workman who can distinguish between these plans of boring and can always determine from the nature of the work which it is proper to adopt, has acquired no small knowledge of machine fitting.

Chuck boring is the usual plan adopted in three kinds of cases. For holes of shallow depth, taper holes, and holes that are screw-threaded.

As the work is overhung in lathe boring there is not sufficient rigidity neither in the lathe spindle nor in the tools to admit of deep boring.

The tools being guided in a straight line and at any angle to the axis of rotation, the facilities for making tapered holes are complete, and as the tools are still, and can be instantly adjusted, this kind of boring is adapted to cutting internal threads, the operation corresponding to cutting external threads, except that the cross motions of the tool block are reversed—that is, the tools are fed to the front towards the operator.

The second plan of boring by means of a bar mounted on points or centres, as they are technically called, is the only plan in ordinary practice of securing true holes; it is, like chuck boring, a lathe operation, and one for which no better machine than a lathe has yet been devised, and it may be added is not required. It is indeed a question whether in ordinary machine fitting there is not a gain by performing all the boring in this manner whenever the rigidity of the boring bar is sufficient without auxiliary supports. Machines for this work could then be used in turning and boring as occasion required, and greater accuracy of the work attained than is possible when the boring bar is supported in annular bearings.

When a tool is guided by its turning on centres, its rotation is perfect. The straightness or parallelism of holes bored in this manner is dependent on the truth of the carriage movement that guides the piece, and this is usually a very perfect movement. This kind of boring is practiced in boring steam cylinders, cylindrical valve seats, and for accurate fitting generally.

The third plan of boring with bars that rest in bearings is more extensively practiced, and has the largest range of adaptation. The distinguishing feature in this plan of boring to which the attention of the apprentice is called is, that the form of the boring bar, and any imperfection in its bearings is communicated to the hole that is bored, and any want of straightness in the bar is also communicated to the hole. This, of course, applies to cases where the bar is fed through fixed bearings placed at one or both ends of the hole. If a boring bar is bent, or out of truth between its bearings, the diameter of the

hole is governed by the extreme sweep of the cutters, but as the cutters move along and come nearer to the rest or bearing, the bar then runs true and the hole is tapered. The same rule, in one sense, applies to chuck-boring, the form of the lathe spindle being communicated to the holes bored; but lathe spindles are presumed to be quite perfect compared to boring bars. Besides it is the form of the spindle that may affect the truth of the hole, while in the case of a boring bar it is the bearings.

The prevailing custom of casting machine frames in one piece or in as few pieces as possible, leads to a great deal of bar boring, nearly all of which is performed accurately enough and much upon this third plan of boring. By setting up temporary bearings to support the bar and improvising means of driving and feeding the boring bars most of the boring can be done without mounting the castings on machines, which would in many cases be impossible.

In but few cases will the learner see the importance of studying principles so clearly demonstrated as in this matter of boring; even a whole life-time of practical experience seldom leads to a thorough understanding of the matter, and questions asked in regard to different plans of boring will be less intelligibly answered than if relating to any other branch of work.

Drilling as an operation differs in principle from almost every other one in metal cutting. The tools instead of being held and directed by guides or spindles, steady and support themselves from the bearing of the cutting edges.

The common triangular pointed drill as a cutting tool is capable of withstanding a greater amount of strain upon its edges, and rougher use than any other implement used in machine fitting. The rigid support which the edges receive and the tendency to press the edges to the centre of the tool instead of to tear them away as in other cases, allows drills to be used that are imperfectly shaped, imperfectly tempered, and even when the cutting edges or lips are of unequal length.

Nearly all of the difficulties that once attended drilling are now removed by the machine-made drills that are manufactured and sold like files, and used generally throughout America, and everywhere else where they are known. Such drills do away with fitting to sizes, dressing and tempering, drill true holes, are more rigid than common solid shank drills, will drill to any depth without clearing the holes, and are safe from breaking except by the most careless use.

Drilling tools, except these modern machine-made drills, have been described so many times, and so thoroughly that no further notice can be of use.

A drilling machine adapted to the various requirements of a machine fitting establishment consists essentially of a spindle arranged to be driven at various speeds, and with an eased movement for feeding the drills; a firm table set at right angles to the spindle, and arranged with a vertical adjustment to and from the spindle, and compound adjustment in a horizontal plane. This would constitute a standard drilling machine, but the simplicity of the mechanism required to operate drilling tools is such that it has led to endless modifications; such as column drills, radial drills, suspended drills, horizontal drills, bucket drills, multiple drills, and others.

Drilling more than any other operation requires the sense of feeling, and comes farther from the conditions that admit of power feed than other operations. The speed at which a drill may cut without heating or breaking is not only dependent upon the manner in which it is ground and the nature of the material drilled, but may change at any moment as the drilling progresses; so that hand feed is the best for drilling, and with machines that are arranged with power feed for boring there should be some means of permanently disengaging the feed to prevent its use in ordinary drilling.

I am well aware how far this opinion is at variance with practice, especially in England; yet careful observation will prove that power feed in ordinary drilling is a mistake.

MILLING.

Milling relates to metal cutting with serrated rotary cutters, and differs materially from either planing or turning, the movement of the cutting edges can be much faster than with those that act continuously, because the edges are cooled during the intervals between each cut; that is, in a milling tool with twenty teeth, any single tooth or edge acts but one twentieth part of the time, and as the cutting distance or time of cutting is rarely long enough to generate much heat, the speed of such tools may be fifty per cent. greater than with turning, drilling, or planing tools. Another distinction is the perfect and rigid manner of supporting the cutting edges, which are short and blunt, besides being carried on short mandrils that insures rigidity. The result of this rigid support of the tools is seen in the length of the cutting edges that can be employed, which are sometimes four

inches or more in length. It is true the amount of material cut away in milling is far short of what the edge movement would indicate when compared to turning or planing tools; yet the displacing capacity of a milling machine exceeds that of either a lathe or a planing machine. Theoretically the cutting capacity or the displacing capacity of any metal or wood cutting machine, is as the length of the edges multiplied into the speed of their cutting movement; a rule that applies very uniformly in wood cutting, and also in metal cutting within certain limits; but the strains that arise in metal cutting are so great that they exceed all means of resisting them either in the material acted upon, or in the means of supporting tools, so that the length of the cutting edges is limited. In turning chilled rolls in Pittsburgh, tools to six inches wide are used, and the effect produced is as the length of edge; but the depth of the cut is slight and the operation is only possible because of the extreme rigidity of the pieces turned, and the tools being supported without movable joints beneath it, as in a common lathe.

A given quantity of soft iron or steel may be cut away at a much less cost by milling than by any other process that would produce the same result, and more accuracy attained.

A milling tool that has twenty edges, should represent as much wearing capacity as a like number of separate tools, and may be said to equal twenty tools that are duplicates; hence, in cutting grooves, notches, or similar work, a milling tool is the equivalent of a large number of duplicate single tools, which cannot be made nor set with the same truth, so that milling secures accuracy and duplication, that is often more important than speed.

As milling operations are cheaper than planing or turning, the question arises, why not mill all surfaces that can be reached, and do all the cutting that is possible in this manner, instead of using single tools? Any one skilled in shop manipulation would at once answer that the cost of milling tools exceeds that of other tools in a degree that would in most cases balance what would be gained in speed; an answer that would be substantially correct, yet one that should not satisfy a learner, but lead to another question: why are milling tools most expensive? Which may be answered as follows:

First. Solid milling tools consist of a number of edges that must retain the same relative position, there being no independent adjustment of these edges they must be combined in one piece, and each

edge stand precisely at the same distance from the axis of rotation; this makes a milling tool a piece of finished mechanism, with accuracy in all of its parts, and something very different from a turning or planing tool that may be roughly shaped and ground to an edge, without any care except as to temper and shape of the cutting point.

Second. Solid milling tools consist of a large number of edges, each of which may be said to depend on all the rest; the derangement of one edge disabling all, for as soon as a single edge breaks, the next in order will have a double duty to perform, and when this one breaks, which is sure to follow, the next edge will have a triple work to do, so that the tool as a whole is dependent upon the endurance of each edge or tooth. It is a reversal of the old adage that "union is strength," for in this case union is weakness.

Third. These conditions limit the use of milling tools to a certain class of work, where the material is clean and soft, and when duplicate pieces are to be made. It is evident that where there is danger of injury to the tools by sand, "hard pins," or any foreign substance in the material milling may become an expensive process. Duplication is in most cases the greatest gain effected by milling; if the apprentice will examine the milling tools in use in an engineering establishment, he will find nine-tenths of them directed to duplication, to cutting grooves of uniform width or making pieces that have the same profile, such as wheel cutting, which is nearly all performed by milling tools.

Many of the difficulties of maintaining milling tools are obviated by using detachable cutters that may be replaced when injured and removed for sharpening; but such a construction of the tools is only possible when they are of large size and when but narrow edges are required. Machines constructed with these detachable tools, and with the plane of rotation parallel to the face of the material, are constructed by an engineering firm in Leeds, England; which for many purposes exceed the performances of reciprocating planing machines. The most extensive experiments that have come within the writer's notice are the milling machines used at Crewe, in England, for cutting away the crank slots in locomotive axles, when the work is 'roughed out' at a rate that far exceeds the performance of any machine that employs but a single tool. The cutters are so arranged that the sum of their cutting action is equal to two or more tools acting continuously, as in turning.

In the manufacture of small arms, sewing machines, and like articles, where the material is always of the best, and where the work is mainly a duplication of pieces, milling can be applied with great success, especially on pieces that are made from crucible steel, which are free from hard spots and may be rendered soft by annealing.

Milling machines, as a class, are among those that admit of endless modification in their arrangement, especially in the means of holding and presenting the material. The essential parts of such machines are a rotary spindle to carry the milling tools, and a traversing platen to hold and feed the material, with an adjustment of the tools to and from the face of the platen.

As there could be nothing gained by following out the details of construction in milling machines, and nothing but what will be at once understood by a learner when he is brought in contact with the machines themselves, the matter is left here with this recommendation to the reader: Accustom the mind to refer continually to the proper method of finishing any piece of work that comes under notice, whether it should be planed on a shaping, slotting, or planing machine, or milled; whether holes should be "chuck bored," or bored with a bar; also, the facilities in favor of these several plans; in short, always keep the mind directed to the operations of planing, turning, boring and milling, because no small share of success in machine fitting must depend upon the choice of proper finishing processes.

SCREW CUTTING.

The processes for cutting screw threads and the tools employed especially for this purpose, constitute a separate class among the implements of the fitting shop, and it is considered best to notice them separately.

Screw cutting is divided into two classes, one where the blanks or pieces to be threaded have axial support, and the tools held and guided independently of their bearing at the cutting edges, technically called chasing; the other process, where the blanks have no axial support, but are guided by the dies and cutting tools.

The first of these operations includes all threading processes where the blank runs on centres, as in lathe cutting, whether performed with a single tool or by dies that are carried positively by the slide rest or by milling processes.

The second includes what are termed bolt cutters, in America, and

screwing machines, in England, consisting essentially of devices to rotate either the blank or the dies, and means of holding and presenting the blank to the cutting dies.

Chasing produces screws that are true with respect to their axis, and is the common process for threading all screws that are to have a running motion in use, either of the screw itself, or the nut.

Die-cutting produces screws that may not be true with respect to their heads, that may not be perfectly straight, but still are sufficiently accurate for most uses, especially in clamping and joining together the parts of machinery.

Chasing operations being in a sense lathe work, and involving no principles not already noticed, I will confine what is said to die-threading and to bolt-threading machines, which as simple as they may appear to the unskilled, involve, nevertheless, many intricacies that do not appear upon superficial examination.

The apprentice will find the following modifications: Machines with running dies where the rotation is performed by what is called the head in which the dies are mounted. Machines with fixed dies in which motion is given to the rod or blank to be threaded; machines with expanding dies that open and release the screw without running back; and machines with solid dies in which the screws have to be withdrawn by changing the motion of the driving gearing; making four different types that are more or less distinct.

If these various plans of arranging thread-cutting machines was with reference to different kinds of work it might be assumed that all of them were right, but as a rule they are all applied to nearly the same kind of work, and hence it is safe to conclude that there is one arrangement better than the rest or that one is right and the others wrong; a matter that is to be determined by following through the conditions of their use and application.

First. As between a running motion of the dies and of the blank.

If dies are fixed, the clamping mechanism to hold the blank has run with the spindle and the blank, and the machine must be stopped while fastening the blanks to be cut. The clamping jaws are usually as little adapted to rotation as the dies would be, if carried on the spindle and generally afford more chances for obstruction and accident; to rotate the blank it must, when long, pass through the driving spindle, as the machines cannot well be made of sufficient length to receive long rods.

In machines of this last class that revolve the blanks, the dies have to be opened and closed by hand instead of the driving power, which can be employed for the purpose only when the dies are mounted on the running head.

With running dies the blank may be clamped when the machine is in motion, and as the blank is still, except the feed movement, it may, when long, be supported in any temporary manner; the dies can be opened and closed by the driving power also, and no stoppage of the machine is necessary, so that several advantages of considerable importance may be gained by mounting the dies in the running head, a plan that has been generally adopted of late years by the best makers of machine tools.

In respect to the difference between expanding and solid dies, it rests mainly in the time required to run back, and in the additional mechanism required to reverse the motion of the driving spindle when solid dies are used.

Uniformity of size in the screws is insured by solid dies, but they are more liable to derangement and less easy to repair than the expanding or independent dies.

The main difference between solid and expanding dies, aside from the precision required in adjusting the latter, consists in the firmness with which the cutting edges are held. With a solid die, the edges or teeth being all combined in one piece, are firmly held in a fixed position, while with expanding dies their position has to be maintained by mechanical devices that are liable to yield under the great pressure that arises in cutting. The result is, that the precision with which a threading machine with movable dies will act, is dependent upon the strength of the "abutment" behind the dies, which should be a hard surface that is unyielding, and with as much area as possible.

Connected with dies, there are various problems, such as clearance behind the cutting edge; whether an odd or even number of edges are best; how many threads require to be beveled to perform the cutting, and many other matters about which there are no determined rules. The diversity of opinion that will be met with on these points, and in reference to taps, the form of screw threads, and so on, will convince the learner of the intricacies in this apparently simple matter of cutting screw threads with dies.

(To be continued.)

Chemistry, Physics, Technology, etc.

THE JOINT EFFECT OF BATTERY-CELLS, WHEN DIFFERENTLY COMBINED.

By John P. Merrell, U. S. N.

In speaking of batteries, each cell is always considered to have a certain electro-motive force and resistance, which depend for their value on the construction of the cell, and which for similar cells may practically be considered uniform.

In practice, battery cells are differently arranged according to the nature of the circuit in which they are placed: they may be arranged *in series*, in which case the positive pole of one cell is connected to the negative pole of the next, and so on; they may be connected *for conductivity*, in which case all the similar poles are connected together; and they may be arranged as shown in the figure, that is, partly in series and partly for conductivity, the connection shown being two *in series* and four for conductivity.

The strength of the current flowing in any circuit and due to any arrangement of battery, may be computed by means of the following formula:

$$S = \frac{xE}{\frac{Bx^2}{n} + R} \quad . \quad . \quad . \quad . \quad (I)$$

In which S = strength of current.

E = electro-motive force per cell of the battery used.

B = resistance per cell of the battery used.

n = whole number of cells.

x = number of cells connected in series.

$\frac{n}{x}$ = number of cells connected for conductivity.

and R = interpolar or external resistance.

The truth of formula (I) may be shown by Gavarret's well-known formulæ, bearing in mind, at the same time, the principle that the resultant current in any conductor will be the algebraical sum of all

the partial currents flowing in that conductor, currents in one direction being considered positive and those in the opposite direction negative.

Gavarret's formulæ apply to cases of branch or derived circuits, in which the current divides between two or more paths; and are,

$$T = \frac{abcd}{abc + bcd + cda + dab} \quad . \quad . \quad . \quad . \quad . \quad (II)$$

$$S = \frac{E'(abc + bcd + cda + dab)}{L(abc + bcd + cda + dab) + abcd} \quad . \quad . \quad (III)$$

$$S_A = \frac{E'(bcd)}{L(abc + bcd + cda + dab) + abcd} = \frac{E'(bcd)}{M} \quad (IV)$$

$$S_B = \frac{E'(acd)}{M}, \ (V) \ S_C = \frac{E'(abd)}{M}, \ (VI) \ S_D = \frac{E'(abc)}{M}, \ (VII)$$

In which E' = the total electro-motive force acting in the circuit.

L = the resistance of the simple parts of the circuit.

T = the equivalent resistance of the four branches, whose resistances are respectively a, b, c and d.

S = the strength of current in the simple parts of the circuit; which equals the sum of all the currents in the branches.

and S_A, S_B, S_C, etc., the strength of current in the respective branches, A, B, C, etc.

Now let us consider the condition of things in a circuit similar to the one shown in the figure, letting E and B represent the electro-motive force and resistance of each cell, and R the external resistance. As far as the cell *a* is concerned, all the other cells may be considered simply as so many conductors, each having a resistance B; and the current given by the cell *a* through a circuit so composed would be in the direction of the arrows, the case being one of branch circuits, in which A is the simple part of the circuit, and F, D, C, and R* the branches. Now A, F, C, and D, each having a resistance equal to 2B, we shall have for the current given by the cell *a* in the part A,

$$S_A = \frac{E\,[3R\,(2B)^2 + (2B)^3]}{(2B)\,[3R\,(2B)^2 + (2B)^3] + R\,(2B)^3 = O}$$ (from formula III);

in the branch R*, $S_R = \frac{E\,(2B)^3}{O}$ (from formula IV).

and in the branches, F, C and D, $S_F = S_C = S_D = \frac{ER\,(2B)^2}{O}$

Now, considering the cell *b* as the battery, and the cell *a* and all others as simply conductors, the current from *b* would be in the direction of the arrows, and its strength in the different parts of the circuit would be the same as that just determined for the cell *a;* and as these currents are everywhere in the same direction their resultants will be the sum of the two, and we shall have for the strengths of current in the different parts of the circuit due to the combined action of the two cells,

$$S_{A_2} = \frac{(2E)\,[3R(2B)^2 + (2B)^3]}{(2B)\,[3R(2B)^2 + (2B)^3] + R(2B)^3}, \text{ etc.}$$

Let us now take a more general case, that of n cells connected x *in series* and y *for conductivity*, (xy being equal to n), and treat it in the same way. In this case each part of the circuit, except the part R, will have a resistance xB; and we shall have for the current in any row of cells, due to their own action,

$$S = \frac{(xE)\,[(y-1)\,R(xB)^{y-2} + (xB)^{y-1}]}{(xB)\,[(y-1)\,R(xB)^{y-2} + (xB)^{y-1}] + R(xB)^{y-1}} = \frac{(xE)\,[(y-1)\,R(xB)^{y-2} + (xB)^{y-1}]}{yR(xB)^{y-1} + (xB)^y} \qquad [M]$$

for the current in the part R due to the action of any row,

$$S_{R_1} = \frac{(xE)\,(xB)^{y-1}}{yR(xB)^{y-1} + (xB)^y} = \frac{xE}{yR + (xB)} \qquad [N]$$

and for the current in any row due to the action of any other row,

$$S_o = \frac{(xE)\,(xB)^{y-2}\,R}{yR(xB)^{y-1} + (xB)^y} \qquad [O]$$

An inspection of the figure will show that (treating each row as above) where we have *y* rows with *x* cells in each, each row will send into the interpolar wire (R) a current whose strength will be expressed by equation (N), and furthermore that all these partial cur-

* The part R is taken throughout this discussion as corresponding to *a* in Gavarret's formulæ.

rents will be in the same direction; therefore, we will have for the resultant current in the wire R the sum of y of these partial currents. Or,

$$S_R = \frac{yxE}{yR + xB} + \frac{xE}{R + \frac{xB}{y}},$$

or, putting $y = \frac{n}{x}$,

$$S_R = \frac{xE}{\frac{Bx^2}{n} + R} \quad \text{(q. e. d.)} \qquad [I]$$

A further inspection of the figure will show, that, in each row there is a current in one direction, due to its own action, and whose valu is expressed by equation (M); and (y—1) currents in the opposite direction, due to the action of the other rows, the value of each of which is given in equation (O). This being the case, the resultant current in each row will be expressed as follows:

$$S' = \frac{(xE)\,[(y-1)\,R(xB)^{y-2} + (xB)^{y-1}]}{yR(xB)^{y-1} + (xB)^y} - \frac{(y-1)\,(xE)\,R(xB)^{y-2}}{yR(xB)^{y-1} + (xB)^y} =$$

$$\frac{(xB)^{y-1}\,(xE)}{yR(xB)^{y-1} + (xB)^y} = \frac{xE}{yR + xB}$$

It will be noticed that the sum of the resulting currents in the y rows equals $\frac{xE}{\frac{Bx^2}{n} + R} = S_R$, which should be the case.

The formula for the case in which the cells are all connected *in series* is readily derived from equation (I). In this case we have but one row and $x = n$, and the formula becomes $S_R = \frac{nE}{nB + R}$.

In the same way when the cells are arranged for *conductivity*, we have n rows, and $x = 1$, and the formula becomes $S_R = \frac{E}{\frac{B}{n} + R}$.

It is easily proved that when, in equation I, $\frac{Bx^2}{n} = R$, we will have the maximum value of S_R. Now, $\frac{Bx^2}{n}$ expresses the equivalent resistance of $\frac{n}{x}$ branches, the resistance of each of which is xB, and as this is precisely the arrangement of the battery we have been consid-

ering, we may say that, "The maximum strength of current from a fixed number of cells (n) working against a definite interpolar resistance, (R) is obtained when the battery is so arranged that its resistance shall as nearly equal the interpolar resistance as possible."

EARTH BORERS FOR TELEGRAPH POLES.

By John Gavey, M.S.T.E.

(Abstract of a Paper read before the British Society of Telegraph Engineers, November 25th, 1874.)*

In the present age, when labor is daily becoming more costly, and labor-saving appliances are gradually superseding mere physical strength in all mechanical operations, it may be well to inquire what improvements have been introduced with the object of reducing the expenditure of manual force in, and the cost of, the erection of telegraph poles. The old method of digging a post-hole by means of a spade and pickaxe is so well known as to need no description. Some years ago a pole 24 feet long by 5 inches diameter at the top was considered a fair length for a main line. Now, lengths of 28 and 30 feet, with a minimum diameter of 6 inches at the top, are as a rule adopted.

The depth at which it is customary to plant telegraph poles may roughly be considered to vary from 4 feet 6 inches for a pole 24 feet long, to 5 feet 6 inches for one 28 or 30 feet; 6 feet serving up to, say, 40 feet, and 7 feet for any height employed beyond.

Now, the number of pole-holes which an ordinary laborer, accustomed to the work, will dig in a working day of ten hours, will obviously depend on the depth which he has to reach, and the soil in which the poles have to be planted. We may assume, as before indicated, that the average depths will vary from 4 feet 6 inches to 5 feet 6 inches, and the soils may conveniently be divided into: 1st, clay; 2d, ordinary soil, requiring some use of the pickaxe; 3d, hard gravel; 4th, chalk; and 5th, rock.

It may be taken as the result of experience that the average number of holes which a workman will dig in ten hours is represented in

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* Reprinted from London *Engineering*.

the following Table:

Soil.	No. of Holes per Day.	
	4 ft. 6 in. deep.	5 ft. 6 in. deep.
Clay	6	5
Digging soil	5	4
Hard gravel	4	3 to 3½

Chalk and rock may for the present be left out of consideration. For these there appears no alternative but the pickaxe, bar, spade, and, occasionally, blasting.

It will, of course, be obvious that the most ready means of diminishing the labor involved by these operations will be the reduction of the size of the hole; for we actually require but a cylindrical space, varying from 10 to 14 inches in diameter, with an average cubical content of 3·5 feet and a weight of materials of 376 lbs. for a 4-feet 6-inch hole; the contents of one 5 feet 6 inches deep being taken at 4·3 cubic feet, weighing 460 lbs.

Perhaps the earliest attempt in this direction was made in Spain, where an instrument since known as a "Spanish spoon" was introduced. This was reported to have worked very successfully. It may be said to have consisted of a section, or arc, of a circular metal disc; the chord of the arc forming a cutting edge. The periphery of the disc was provided with a ledge about two inches high, to retain whatever might accumulate on its surface, and the whole was fixed at right angles to a long handle. To dig a hole with this machine, the soil was first loosened by means of a bar, and the machine being inserted, a circular or rotary motion was imparted to it, by means of its handle, whereby the loosened soil was accumulated on its surface and removed from the hole.

A similar instrument was tried in this country, but the results obtained were not so satisfactory as was expected.

The average speed with which a pole-hole, varying from 4 feet to 4 feet 6 inches, was dug, did not exceed that of the ordinary method; but, of course, an advantage was presented by the new system in the additional solidity of the pole when erected, and in the diminution of the quantity of soil which had to be filled and rammed in. It was observed that after a depth of about 3 feet 6 inches had been reached, the difficulty of loosening and collecting the soil appeared to increase,

and the speed of working to decrease, as the square of the additional depth, so that the plan did not at that time promise much success with deeper holes for heavy timber.

The most marked improvement in the method of forming holes for telegraph poles appears to have been the introduction of earth borers, amongst which may be mentioned those invented by Spiller, by Marshall, and by Bohlken.

In most soils these instruments obviate the necessity of breaking up and loosening the materials with a bar, and moreover they collect the débris with much greater facility than is possible with a Spanish spoon.

Spiller's borers may be described as a huge modification of the old-fashioned ship's auger. It consists of a plate of sheet iron, bent into the form of a semi-cylinder, attached vertically to a long handle. At the lower extremity, and at right angles to it, are two quadrants of sheet steel, one slightly bent downwards, which forms the cutting plate, the other, which occupies the second half of the semi-cylinder, is bent upwards, and serves to retain the débris as it is cut up by the lower plate.

Marshall's borer is thus described in his specification:

"The auger blade is made of a flat plate or disc of metal, severed in a radial direction from the centre or boss, on which the blade is carried, to the circumference, the two ends of the blade thus formed being bent apart of a V form in edge view. The edge or point which is bent downwards or projects from the lower surface of the blade forms the cutting edge, the earth removed thereby on the rotation of the auger passing through the radial opening between the two ends on to the upper surface of the plate, whence it is removed from time to time by raising the auger. The auger or blade is fixed at right angles on its shank or stock, which is formed with a square end to receive the boss of the blade. The latter is secured by a tapering metal point screwed on to the extremity of the stock. The point is provided with a quick spiral groove or grooves to form a reamer for the purpose of drilling a hole in advance of the boss of the auger, and so facilitate the penetration of the latter. The stock of the auger is attached to two or more sections of tubes screwed together and provided with sockets for the cross handle used for rotating the auger."

Bohlken's borer is an instrument very similar to that introduced by Marshall. The principle appears to be exactly the same.

These borers should invariably be accompanied by a narrow long-handled shovel and a punner bar, so called. This bar consists of a long hollow rod, at one end of which is a chisel point for loosening the soil, breaking and removing stones, etc., and the other a peculiarly-shaped punner head for ramming and consolidating the soil around this when it is erected. The shovel is found to be of much service in removing stones and other obstructions which interfere with the passage of the auger. These augers are worked by two men who rotate them steadily, withdrawing them from time to time with their superincumbent load of soil.

Spiller's borer was found by the author to be very effective in sand, clay, and ordinary soil. It, however, was not so successful in gravel, as it would not bore through it. The whole of the material had to be disturbed and broken with a bar, the borer then simply acting as a spoon, and a somewhat clumsy one, to remove the débris. Moreover the radial opening between the plates appeared too small to admit of the passage of ordinary gravel and stones. It is, however, probable that the instrument might be so modified as to give better results with the last-mentioned soil. The machine itself is very strong, will bear much rough usage, and does not appear likely to break or get damaged by hard work.

Marshall's borer is very effective in clay, ordinary soil, and gravel. It does not simply bore into the ground like a common screw pile, for then it would be impossible to withdraw it. The action of the cutter takes slice after slice of the soil, raising each through the height of the groove, thereby severing it from the circumference of the hole, without otherwise disturbing its position. A small valve exists in the tapering point of the machine, which is movable by means of a lever or eccentric and connecting rod which passes down the hollow stem. The object of this is to admit of the introduction of air under the plate in such soils as would otherwise tend to form a vacuum on the withdrawal of the closely packed borer, thereby adding the weight of the atmosphere to that of the materials raised.

The cutting plates, which are interchangeable, vary from 10 inches to 12 inches in diameter. These sizes will, as a rule, serve for the majority of poles erected; but the hole can, if necessary, be easily enlarged with a properly-formed shovel, by cutting down the sides and raising the soil with a borer.

With this machine, a hole has been bored a depth of 5 feet 6 inches, in clay, by two men, in 20 minutes, and the pole erected and com-

pleted in half an hour; and holes in gravel have been opened up a like depth, in a time varying from 30 minutes to an hour with the same strength.

There is obviously a very considerable saving of labor in filling in and ramming the bored hole, as compared with that dug in the ordinary manner. It may be mentioned that in boring through gravel it is found necessary to drive the bar down the centre of the hole, well in advance of the borer, to admit of the entrance of the tapering point which forms the extremity, in order to get through the gravel at a fair speed. The ordinary rotating motion does the remainder of the work.

Bohlken's borers appear the same in principle as Marshall's, and would probably do like work. The author has not used them.

These borers have obviously one defect. They cannot be worked close to a wall or a hedge, positions where, in road telegraphy especially, it is frequently necessary to erect poles This difficulty has been overcome by fitting one of the borers with an ordinary rachet handle, lightening such of the parts as admit of it, and replacing the long tapering point by a shorter one. This modified instrument will bore in clay and ordinary soil, but in gravel it only acts as a spoon, the soil having to be broken up with a bar.

The advantages of these apparatuses may be summarized as follows:

1. *Speed.*—A number of pole-holes can be opened out to a given depth, with the same force of men, in less time than by ordinary methods.
2. Diminution of labor in filling in.
3. Greater solidity of the pole thus erected.
4. Less disturbance and mixing up of the soil, a point of some consequence in erecting lines of telegraph through private property.
5. The advantage of being able to work in wet soils without baling or pumping.
6. Saving of expense in sharpening and laying pickaxes.

Among the disadvantages may be mentioned:

1. Strain involved in raising the borers out of heavy soils with their load of débris.
2. The difficulty, and, with inexperienced men, danger, in rearing the pole into the hole, when the former is very heavy.
3. Liability of the screw borers to fracture, and additional first cost.

After the reading of the paper, Mr. Gavey explained the various apparatuses and the method of working them.